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INSTITUTE OF PETROLEUM.

An Ordinary General Meeting of the Institute of Petroleum was held at Manson House, 26 Portland Place, London, W.1, on Wednesday, February 8, 1950, with the President, Mr E. A. Evans, in the Chair.

The Minutes of the preceding Ordinary General Meeting, held on January 11, 1950, were read, confirmed, and signed.

The General Secretary (D. A. Hough) read the list of members elected since the preceding meeting.

The President: This evening we are privileged to have presented to us by Mr Kirby a paper on the Heysham refinery. Many of you will know that that refinery was one of the mysteries of the war. Now the facts are being revealed, and Mr Kirby, who was the general manager during the reconstruction and at the start of the operation of the refinery in its new guise, will tell us of some of the difficulties encountered and some of the great feats achieved in the transformation from the wartime effort to peacetime operation.

HEYSHAM REFINERY—A STUDY IN ADAPTABILITY.

By A. W. W. Kirby (Member).

Summary.

During the war, the Trimpell factory at Heysham was operated jointly by the Trinidad Leaseholds Ltd., Imperial Chemical Industries Ltd., and the "Shell" Refining and Marketing Co. Ltd., on behalf of the Government for the production of 100-octane aviation spirit, which was produced from a gas-oil feedstock by high-pressure catalytic hydrogenation. After the war this work was stopped, and the oil plants at Heysham lay idle until the beginning of 1948.

On February 1 of that year, the plants which had been used for processing the hydrogenated gas oil were purchased by the "Shell" Refining and Marketing Co. Ltd., and were redesigned and modified with the object of using them for conventional distillation of crude petroleum at an annual throughput of 1½ million tons, in order to help bridge the gap which existed between the world-wide demand for petroleum products and the shortage of refinery capacity. A vast amount of work was accomplished in the first three months, which involved the transfer of much equipment from one plant to another, together with the reorganization of the storage and distributional facilities to handle a daily quantity of oil three times as great as that for which these facilities had been designed.

The original functions of the various plants are recounted briefly, and the plants as they are now operating are described in detail. An account is also included of the difficulties which were inevitably encountered in a project of this nature, together with the steps taken to overcome them.

Introduction.

The Trimpell factory at Heysham (Fig. 1), as originally constructed by Messrs Trinidad Leaseholds Ltd., Imperial Chemical Industries Ltd., and "Shell" Refining and Marketing Co. Ltd., has been described in detail by

Oriel and Gordon.* Very briefly, the process was as follows. Gas oil, imported from America, was stored in underground tanks and transferred as required to the factory, where it was given a preliminary redistillation.

Hydrogen was prepared by means of the water–gas reaction, carbon monoxide being catalytically converted to form, with additional steam, more hydrogen. Final traces of carbon monoxide were removed by ammoniacal copper liquor, after compression to 350 atm.

The hydrogenation of the gas oil took place in two stages, the first essentially to remove nitrogen compounds as ammonia, the nitrogen compounds being a poison to the catalyst used in the hydrogenation reaction proper, which took place as a second stage. The result of this process was

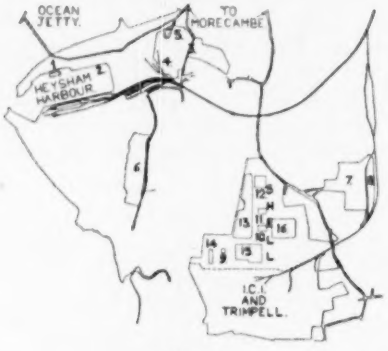

FIG. 1.

HEYSHAM SITE PLAN.

1. Pontoon berth.
2. North Wharf berth.
3. Aviation Fuel Reserve Depot.
4. Main loading gantry.
5. Road loading gantry.
6. Crude tanks.
7. Finished products tank farm.
8. Rail loading gantry.
9. No. 1 distillation unit.
10. No. 2 distillation unit.
11. No. 3 distillation unit.
12. Catalytic treating unit.
13. Rundown and feed tanks.
14. Feed tanks.
15. } Rundown tanks.
16. }

really a synthetic crude oil containing everything from methane up to practically unchanged gas oil. It was stored as liquid and rich gas, and was distilled to produce propane and lighter hydrocarbons used as fuel gas, propane which was bottled, butane, aviation base spirit, and a residual fraction which was recycled for further hydrogenation. The butane segregated in this distillation was then processed for the production of mixed *iso*-octanes by dehydrogenation to butylenes, which were polymerized to mixed *iso*-octylenes. The *iso*-octanes were obtained therefrom by a final hydrogenation using the hydrogen produced in the dehydrogenation stage. High-octane aviation spirit was then blended from the base spirit, *iso*-octane, T.E.L., and other additives.

Construction of the factory was begun in September 1939 and commenced operating in August 1941. From that date aviation gasoline was

* Oriel, J. A., and Gordon, K. "Aviation fuel production." World Power Conference, The Hague, 1947.

in continuous production until VE-Day. Thereafter, the demand for aviation gasoline fell rapidly, but the factory continued to manufacture ammonia, which was still required particularly for fertilizers, and motor gasoline instead of aviation spirit. This was an expensive process for obtaining petrol, and after the cessation of Lease–Lend it became entirely uneconomic. During 1945 and the first half of 1946, therefore, oil operations at Heysham gradually faded out.

In the years 1946 and 1947 there was a world-wide shortage of all petroleum products, due to refinery construction and development not keeping pace with the increase in demand throughout the world. In the European and Eastern hemispheres, the disparity between demand and refinery capacity had been aggravated by the number of refineries that had been put out of action during the war. So far as Britain was concerned, this meant that much of the import of essential petroleum products had to be paid for in dollars. Crude oil was available in sterling areas, but the refineries for converting the crude into usable products were not.

The Heysham plant had been designed for a very special and rather unusual purpose, but on the gas-oil distillation plants, on the light-oil (synthetic crude) distillation plants, and on the *iso*-octane units, there was equipment, such as pipe stills, distillation columns, condensers, heat-exchangers, and pumps, which were identical with, or very similar to, conventional equipment used for the distillation of crude petroleum. All that was necessary was that these units of equipment should be tied together in a rather different fashion to make them suitable for crude-oil distillation.

On February 1, 1948, the oil plant at Heysham was purchased from the Government by the " Shell " Refining and Marketing Co. Ltd., and its conversion for its new duties was a period of intense activity. During the purchase negotiations, the Government had insisted that the plant be used in such a way as to give the highest possible throughput and should start operation in the shortest possible time. The Shell Company gave an undertaking that one plant would be in operation in one month from the time of purchase, and that all three of the planned units would be operating within four months.

A skeleton crew of key staff with previous experience at Heysham, was available from other Shell refineries, but Heysham lies in an area which is very little industrialized, and hence the availability of skilled engineering workers, in particular, is not good. For this reason, the necessary large crew of engineering workers was borrowed from Shell's Stanlow refinery in Cheshire. This crew, at its highest, totalled some 240 men. The amount of work undertaken in the target time was considerable. In the first thirty days, 5 miles of new pipeline were laid and 15 miles of existing pipeline were modified. This was in addition to the modification of tanks and distillation columns, the building of a new boiler battery, the installation of new pumps, and a multiplicity of instrument and electrical alterations. In the same period, 10 miles of welding rod were used. The first plant was actually started up five weeks after the commencement of work, and the whole refinery was operating at its scheduled throughput of 1½ million tons per annum in four months.

From the outset, it was proposed that Heysham should process crude

from the Kuwait oilfield. This is a paraffinic asphaltic crude with properties as shown in Table I.

In the early stages of the redesigning of the plant, it was obvious that a simple process was essential. This decision was based partly on the necessity for simplifying the actual revamping so that the plant could be operating in the shortest possible time; it was also necessary because of the complete absence at Heysham of any equipment suitable for the chemical refining of intermediate cuts, such as kerosine or white spirit. It was decided, therefore, that only three products would be attempted—motor gasoline, gas oil, and fuel oil. Of these three, the only one requiring chemical treatment was the gasoline, and facilities already existed for its treatment by caustic soda and sodium hypochlorite to give a "Doctor sweet" product. It was realized that there were operational difficulties

TABLE I.

Approximate Properties of Kuwait Crude.

Sp. gr. at 60°/60° F.	0·866
Viscosity, Redwood I at 100° F	52 sec
Sulphur	2·4 per cent wt
Vapour pressure (Reid) at 100° F	10·1 p.s.i.
Pour point	<0° F
Asphaltenes	1·0 per cent wt
Distillation A.S.T.M.	
I.B.P.	38° C
5 per cent vol recovered at	84° C
10 " "	117° C
20 " "	173° C
30 " "	230° C
40 " "	287° C
Vol recovered at 300° C	43 per cent
Vol residue	56 "
Vol loss	1·0 "

involved in this very simplicity, because the absence of a cut intermediate between the gasoline and the gas oil would make it difficult to obtain the latter with a flash point above the minimum requirement of 150° F, and with a volatility which would satisfy the Customs specification, while making a gasoline from Kuwait crude sufficiently light to have an octane number of seventy when leaded with $1\frac{1}{2}$ cc T.E.L/U.S. gal. This difficulty was partly overcome by cutting deeper into the crude than would be necessary for making a straight-run residue to meet a maximum viscosity specification of 950 sec Redwood I at 100° F. Part of the gas oil so produced was then used to blend back the heavy residue to the required viscosity.

Preliminary evaluation had shown that three products could be prepared from the crude, as set out in Table II.

The scheme proposed was to combine the two gas-oil distillation units into one crude unit (No. 1) and to use each of the two light-oil distillation units as a separate plant (Nos. 2 and 3). Each of these units would produce unstabilized gasoline, gas oil, and fuel oil. The unstabilized gasoline was to be run down to common storage and stabilized in a column on No. 3 Unit, together with all rich gas collected from the vapour spaces of crude storage tanks and from the condensing systems of the main crude columns of all three units. On No. 1 unit there was provision for the stripping of its own gas-oil production, but the gas oil produced by both Nos. 2 and 3

TABLE II.

Properties of Products Obtainable from Kuwait Crude.

	Gasoline (unstabilized).	Gas oil.	Residue.
Sp. gr., 15°/4° C	0·700	0·823	0·974
Viscosity, Redwood I at 100° F, sec	—	32	7280
Flash point, P.M., ° F	—	158	417
Pour point (max), ° F	—	<0	59
Sulphur, % wt	0·02	0·8	3·9
Octane No. (+ 1½ cc T.E.L/U.S. gal)	70	—	—
Vapour pressure (Reid) at 100° F, p.s.i.	14·4	—	—
Distillation :			
I.B.P., ° C	25·9	179	—
10 per cent recovered at ° C	51·5	202	—
20 " "	67	214	—
30 " "	81	225	—
40 " "	93·5	237	—
50 " "	104	251	—
60 " "	113·5	266	—
70 " "	123	283	—
80 " "	133·5	303	—
90 " "	144·5	327	—
F.B.P., ° C	159	355	—

units was all to be stripped on a column on No. 2 unit. In the case of all three plants, the heavy residue stream was to be cut back with some of the gas oil produced on the unit before running down to storage. It will be seen, therefore, that to a considerable extent the three units were to be

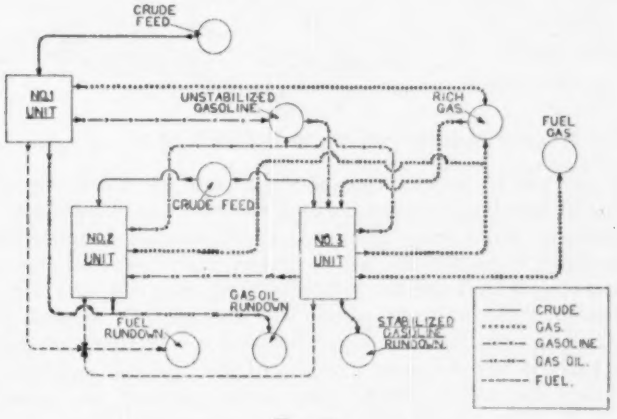

FIG. 2.

HEYSHAM REFINERY FLOW SCHEME.

interdependent. This might have led to difficulties in arranging the general refinery programme, but, as will be seen later, this inflexibility was much improved in the development of the plants subsequent to their original start up. The general scheme is shown in Fig. 2.

No. 1 Distillation Unit.

The two original gas-oil distillation units (Fig. 3) were converted into No. 1 crude distillation unit. The original function of these units had been the preliminary redistillation of the gas-oil feedstocks. Approximately 95 per cent of the gas oil was taken as an overhead product, half this quantity being distilled under atmospheric pressure, and the remainder under vacuum. This technique was adopted in order to avoid any incipient cracking of the gas oil, which would have had undesirable effects in the hydrogenation process.

In the original function of the units, the charge was pre-heated in three horizontal heat-exchangers successively and was then heated in a pipe still consisting of a convection section behind a bridge wall and radiant tubes in the roof. The oil left the furnaces at a temperature of the order

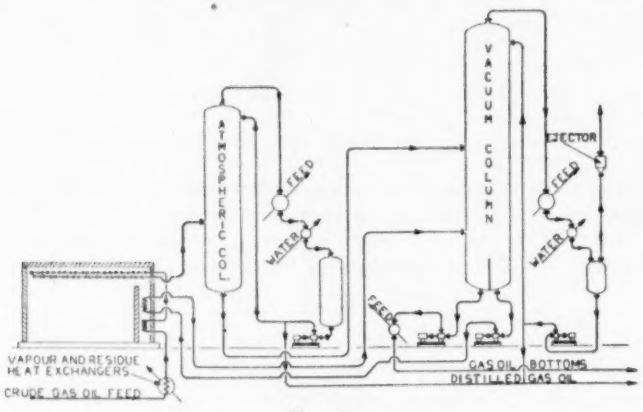

Fig. 3.

ORIGINAL GAS OIL DISTILLATION UNIT.

of 300° C and passed to the atmospheric column, in which approximately 50 per cent of the charge was vaporized, the bottoms being charged to the vacuum column, which was operated at approximately 40 mm mercury.

The overhead vapours from both columns, after heat-exchange with the charge, were condensed and the products pumped to common storage.

The bottom of the vacuum column was divided by a division plate and from one half a portion of the column bottoms was recirculated through the top forty tubes in the convection section of the tube still and back into the column below the bottom tray. The bottom product was pumped from the other half of the column bottom and, after heat exchange with incoming crude, was run down to storage. It was then used in the factory as fuel oil. A small amount of reflux for column-top temperature control was automatically by-passed from each overhead product stream.

In the redesigned unit (Fig. 4), the vacuum column of the north unit was used as the main crude distillation column. The atmospheric column of the same unit was used as a fuel-oil stripper, and an additional column was fabricated and installed for stripping a gas-oil sidestream taken from the

main column. The capacity of the fractionating equipment was adequate for the throughput required, but the tube still was too small for its new function; therefore the tube still of the south unit was used in parallel with that of the other unit. The original feed tanks and feed pumps were used, but an additional feed pump taken from the other unit was put into commission, as it was necessary to have two operating with one spare.

The crude now flows in series through the tubes of two vapour heat-exchangers; and then through the tubes of three residue heat-exchangers in series. It is then divided into two streams, one stream flowing to the south heater, the other to the north. The flow to each heater is again divided into two, both streams being in each case flow controlled: one flows through the radiant section, and the other through the convection section. The flow in the convection section is through all the seventy-two

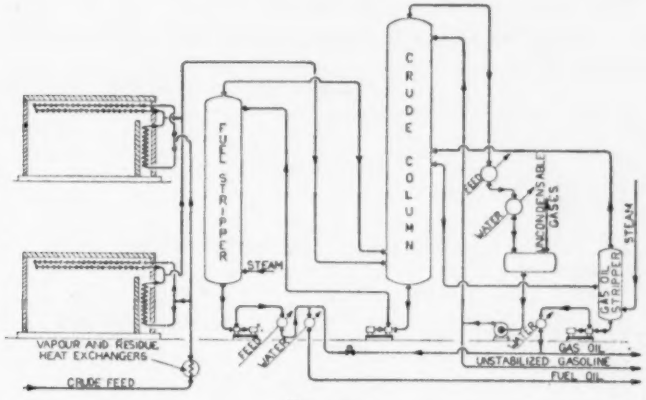

FIG. 4.

MODIFIED FOR CRUDE OIL DISTILLATION.

tubes, entering the bottom tube first. The flow in the radiant section is in series throughout, entering the top row first. The temperature of the oil leaving the radiant section in each heater is controlled by an automatic fireman, while the flow through each convection section is set by means of its flow controller to maintain an outlet temperature equal to that of the radiant section. As a safety measure, there is a high-temperature alarm on the outlet of the convection section.

The heated crude enters the bottom of the main column. Unstripped fuel oil leaves the bottom of this column and is charged to the fuel-oil stripper by three reciprocating steam-pumps, two operating and one spare. The fuel oil is steam stripped, and is then pumped through the crude heat-exchangers and a water-cooler to storage.

Both the third and seventh trays in the main column were modified to provide alternative outlets for a sidestream. From one or other of these trays the gas-oil sidestream gravitates via a 6-in line to a stripper. Stripping is by steam, and the product is pumped to storage by one of three reciprocating steam-pumps through a cooler.

The gasoline vapours leave the top of the main column by a 20-in line

and divide into two streams, each passing through the vapour/crude heat-exchangers already described, and then through two condensers. Reflux is provided by two two-stage turbine-driven centrifugal pumps, and the column-top temperature control is by automatic regulation of the reflux. The reflux pump handles both reflux and the unstabilized gasoline flowing to storage, there being a back-pressure controller in the latter stream to provide the necessary pressure for reflux requirements.

The stripped fuel oil has a viscosity of 2000 sec Redwood I at 100° F, and is cut back with gas oil on the unit by means of a flow controller, so that the fuel oil run down to storage from the unit has a viscosity of approximately 900 sec. A back-pressure controller is installed in the gas-oil rundown stream to provide the necessary pressure for cutting back the fuel oil. Average operating conditions are shown in Table III.

TABLE III.

Average Plant Operating Conditions (No. 1 Unit).

	Pressure, p.s.i.	Temp, ° C.	Flow.
Feed	—	12	1525 tons/day
Heater :			
Inlet	123	100	—
Outlet	19	287	—
Crude columns :			
Top	9	123	—
Bottom	16	280	—
Gas-oil sidestream	—	197	—
Gas-oil Stripper :			
Top	10	184	—
Bottom	13	157	—
Steam	—	—	2030 lb/hr
Fuel-oil Stripper :			
Top	13	269	—
Bottom	18	259	—
Steam	—	—	2670 lb/hr

NOS. 2 AND 3 DISTILLATION UNITS.

These two units were originally the two light-oil distillation units (Fig. 5), whose function was the fractionating of the vapour-phase crude produced by hydrogenation. The two units were identical, and each consisted of four fractionation columns. The pre-heated liquid charge was fed to the first column (stabilizer), and two fractions were taken from the top and bottom of the column respectively. The cut was made in the middle of the C_5 fraction, the tops thus consisting of C_5 and lighter, the bottoms being C_5 and heavier.

The bottoms flowed under pressure difference to the petrol column, in which an aviation base spirit was taken as a top product. The bottom product, known as " recycle oil," was returned for blending with fresh feed to the hydrogenation stage.

The condensed tops from the first column were fed by centrifugal pumps to a depropanizer column to which was also fed, by means of compressors, the rich gas which had been produced in the hydrogenation of the gas oil. Again, in this column only top and bottom products were separated. The

former, consisting of propane and lighter, was used partly as fuel gas in the factory and partly, by means of the methane–steam reaction, for the preparation of hydrogen.

The bottom product, consisting essentially of butane and pentane, was fed by pressure difference to a debutanizer column, in which butane was removed as a top product and pentane as a bottom product. The latter was blended on the unit into the aviation base-spirit stream.

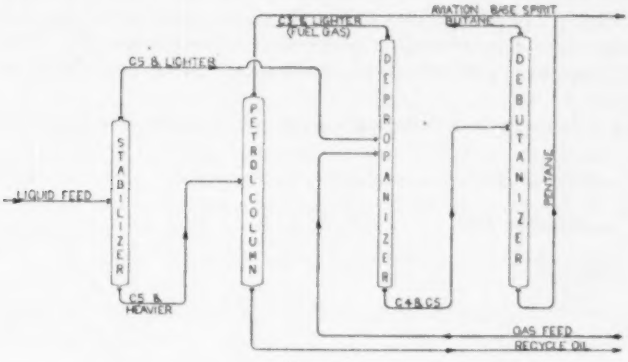

FIG. 5.

ORIGINAL LIGHT OIL DISTILLATION UNIT.

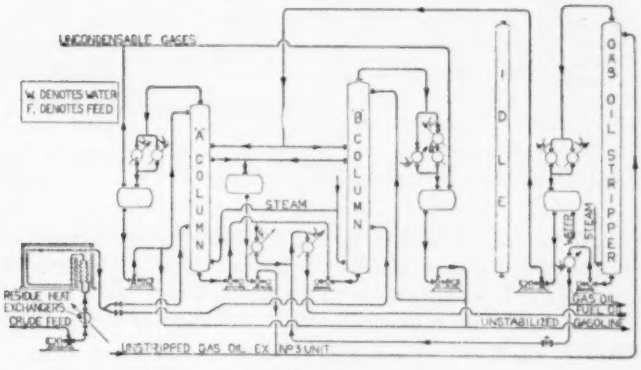

FIG. 6.

FIG. 5 AS MODIFIED FOR NO. 2 DISTILLATION UNIT, INCORPORATING A STRIPPING COLUMN.

The principle of control was identical in all four columns. It was attained by controlling the column-base temperature, the column pressure, and the reflux. The heat for distillation was supplied by heat exchange, there being a hot-oil circulating system, the heat medium and not the process oil being circulated through the pipe still. Control of heat to each column's reboiler and to the charge pre-heater was obtained by temperature controllers operating control valves in the hot-oil circulating system.

The following description of the two units (Figs. 6 and 7) as they are

now arranged is applicable to both units, with a few minor exceptions in so far as the primary distillation of the crude is concerned. The main differences between the two units are that No. 3 distillation unit incorporates a stabilizer column in which the gasoline of all three units is stabilized, and that No. 2 unit incorporates a stripping column for the gas-oil production of both Nos. 2 and 3 units.

Crude oil is stored in three feed tanks and charged to each unit by two centrifugal pumps. On both units there is an additional centrifugal pump as a standby. The crude flows to the tube side of three residue/crude heat-exchangers via a flow-recording controller. The charge then flows to the tube still, the design of which has been modified several times to suit its new duty.

There are two crude distillation columns in parallel, the former stabilizer

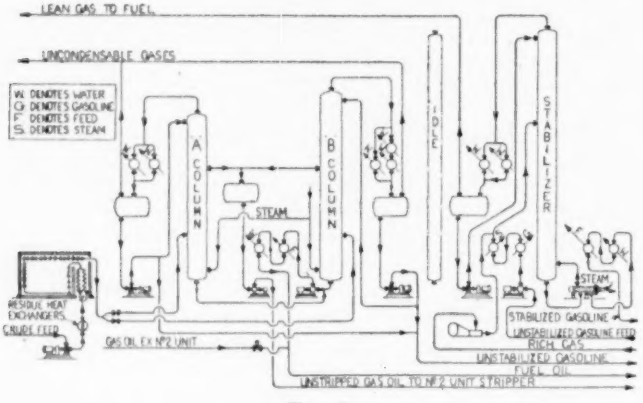

FIG. 7.

FIG. 5 AS MODIFIED FOR NO. 3 DISTILLATION UNIT, INCORPORATING A STABILIZER UNIT.

being known as " A " column, and the former petrol column as " B ". The 10-in transfer line from the heater has a fabricated Y-piece (the plane of the arms of the Y being horizontal), which splits the flow into a 6-in line to " A " column and an 8-in line to " B " column. Flow is proportioned to the columns by means of " V-reg " valves.

" A " column overheads flow along an 8-in vapour line to two condensers in parallel. " B " column overheads pass via a 10-in vapour line through three condensers, of which two are arranged in series with the third in parallel with them. The flow of vapours in the two unequal parts of this condensing system is controlled by adjustment of valves in the vapour lines. Uncondensed vapours pass from the condensate accumulators into the rich-gas system via mist extractors, which are vessels packed with Raschig rings. The unstabilized gasoline storage tanks are twenty-four horizontal 36 ft $\times$ 10 ft vessels, formerly used for butane.

Vaporized 5 per cent ammonium hydroxide solution is continuously injected into the overhead vapour lines to neutralize acids. The amount injected is measured by a rotameter and controlled by the pH (6·5–7) of

the water which is drained from the reflux accumulator. The reflux pumps take suction from the respective accumulators, returning reflux for the control of column-top temperature; the balance goes to storage under level control.

Gas oil from both columns flows by gravity from tray 12 by a 4-in line to an accumulator which, on No. 3 unit, is the former petrol-column reboiler with the tube bundle removed, and on No. 2 unit is an *iso*-octane unit knock-out drum.

On No. 3 unit, one of two turbine-driven centrifugal pumps takes suction from the bottoms of both columns along 6-in lines into a common 10-in header, delivering the residue to the shell side of the crude/residue heat-exchangers. Levels are held in both columns; in the higher-pressure column the liquid-level controller operates a valve on the line from that column only, and in the lower-pressure column the level controller operates a valve on the pump delivery. By this arrangement the pump cannot lose suction on one column. The residue is steam stripped in the lower section of both crude columns of both units.

On No. 2 unit, there is one steam simplex residue pump for each column and a common spare duplex pump.

Flow after the heat-exchangers for both units is through three coolers in series and then to storage.

Gas Oil Stripper (*No. 2 unit only*).

Steam duplex pumps take suction from the respective gas-oil accumulators of each unit, and a common 4-in delivery feeds the column. The charge is steam stripped, and the overheads pass along an 8-in vapour line to the two original condensers in parallel.

One of two centrifugal pumps takes suction from the tops accumulator, returning condensate as intermediate (tray 15) reflux to both of No. 2 unit crude columns. Water separates in the accumulator and is continuously removed. For anti-corrosion purposes, there is an ammonium hydroxide injection system in the overhead vapour line.

A centrifugal pump delivers the stripped gas oil under level control to storage along a 4-in line via a water-cooler.

Stabilizer (*No. 3 unit only*).

Unstabilized gasoline is fed along a 4-in line to the stabilizer column under flow control by means of two duplex pumps. The feed is heated in a feed/product heat-exchanger and a steam pre-heater. It is then joined by rich gas from the compressors. These are Worthington-Simpson horizontally opposed double-acting two-stage compressors driven by direct-coupled 400-h.p. variable-speed induction motors. The capacity of each compressor is 1900 cu. m/hr at a suction temperature of 100° F, with a maximum delivery pressure of 350 p.s.i. The motors are variable in speed between 100 and 226 r.p.m., the speed control being obtained by an electrolytic controller, which varies the resistance in the rotor circuit of the induction motors.

There are three 3-in inlets (trays 32, 28, 24) and one 4-in (tray 20) inlet to the column. The column tops pass along an 8-in vapour line and are

condensed in the two original debutanizer condensers arranged in parallel. All the condensate is returned as reflux by the original debutanizer reflux pumps along a 4-in line, uncondensed gases passing to the fuel-gas system via a back-pressure controller. Water to the condenser is controlled by the level in the reflux accumulator. Column bottoms flow along an 8-in line to a steam-heated reboiler, which has a 12-in vapour-return line to the column. The bottoms under level control in the reboiler pass to the shell side of the heat-exchanger and thence to four coolers arranged for series-parallel flow.

Chemical Treatment.

The stabilized gasoline is given a simple chemical treatment with caustic soda solution followed by a wash with sodium hypochlorite solution.

Gas Systems.

Rich-gas Systems.

Gas from the three distillation units is held on balance with a water-sealed gasholder and fed to the stabilizer by the compressors. In addition, all crude-oil and unstabilized gasoline storage tanks are connected to the gasholders. The pressure held in this system is 6 in of water.

Fuel-gas System.

The stripped (no pentane) gas from the stabilizer is stored in two fuel-gas storage tanks, each 12 ft dia × 59 ft 6 in long, at a maximum pressure of 50 p.s.i. The gas is burned on refinery heaters and boiler plant at 7 p.s.i.g.

Average operating conditions on Nos. 2 and 3 units are shown in Tables IV and V.

Table IV.

Average Plant Operating Conditions (No. 2 Unit).

	Pressure, p.s.i.	Temp, ° C.	Flow.
Feed	—	12	1700 tons/day
Heater :			
Inlet	98	92	—
Outlet	25	279	—
Column " A " :			
Top	3	110	—
Bottom	5·5	—	—
Intermediate reflux	—	—	1150 gal/hr
Steam	—	—	2040 lb/hr
Column " B " :			
Top	3	116	—
Bottom	6·5	—	—
Intermediate reflux	—	—	1350 gal/hr
Steam	—	—	3610 lb/hr
Gas-oil Stripper :			
Steam	—	—	3250 lb/hr

TABLE V.

Average Plant Operating Conditions (No. 3 Unit)

	Pressure, p.s.i.	Temp, ° C.	Flow.
Feed	—	13	1700 tons/day
Heater :			
Inlet	96	96	—
Outlet	32	278	—
Column " A " :			
Top	9	111	—
Bottom	11	—	—
Steam	—	—	2660 lb/hr
Column " B " :			
Top	7	121	—
Bottom	9	—	—
Steam	—	—	2980 lb/hr
Stabilizer :			
Feed :			
Gasoline	—	—	860 tons/day
Rich gas	—	—	108 ,,
Reflux	—	36	293 ,,
Column top	164	58	—
Preheater outlet	—	147	—
Reboiler	—	161	—

INITIAL OPERATING DIFFICULTIES.

A certain amount of teething trouble was experienced in the commissioning of No. 3 distillation unit, which was the first to be brought in line. Little or no difficulty was encountered with the other two distillation units, and this was largely due to the experience gained in initial operation of the first unit.

In order to appreciate the reasons for these troubles in No. 3 unit, it is necessary to remember that the revamping design work had been limited by the following factors. First, maximum throughput was required, and revamping had to be completed in a period so short that no new equipment could be purchased in time for the installation. Calculations had shown that this would be best attained by arranging the available equipment to process to the limit of the thermal capacity of the heaters. This necessitated the operation of certain columns, pumps, and pipelines on a heavy overload. As an instance of this, one of the columns had to operate at a vapour loading 50 per cent in excess of the conventional design figure. Secondly, it was inevitable that the selection and arrangement of certain equipment could not conform to ideally good practice; and, thirdly, the uses of many pieces of equipment being unconventional, it was difficult to evaluate their performance accurately. However, the initial operating problems were not as numerous as might have been expected.

The major difficulty experienced with commissioning No. 3 unit was severe bowing of certain of the radiant tubes in the heater, especially those on the bridge wall. The flow of oil through the radiant section of this heater in its original function was down the bridge wall, along the floor, up the burner wall, and along the roof. The return headers of the radiant section were all of the plug type and of the four-hole pattern, there being parallel flow along two adjacent tubes to the header, where the streams

joined and were reversed, returning as parallel streams via the adjoining set of twin tubes.

The evaporation of the crude commenced just before its entry to the bridge wall tubes, and the linear velocity of the gas and liquid mixture in these 6-in o.d. tubes was insufficient to ensure the presence of a homogeneous mixture of vapour and liquid. Hence, there was a tendency for vapour to travel along the upper tube of each set of the twin tubes of the vertical bridge wall, and for liquid to travel along the lower tube, the heat-transfer rate to the vapour, under these conditions, being much inferior to that of the liquid. The upper tube of each twin set became considerably hotter than the lower and, as the tubes are 40 feet long, there was considerable bowing of the upper tube of each twin set. The floor and burner wall tubes also arched to some extent.

The trouble initially was overcome by installing cores of 4-in line pipe, nearly closed at each end, in the bridge-wall tubes, and of 3-in line pipe in the floor and burner-wall tubes. After some months of satisfactory operation, some of the cored tubes overheated and burnt out, probably because the cores touched the furnace tube at certain points.

The final design, which has proved satisfactory, was to instal single flow with the aid of new two-hole headers on the bridge wall and burner walls, with parallel flow across the roof with the original four-hole headers. The floor tubes were eliminated entirely, because they were only 3 feet below the centre line of the burners and therefore subject to flame impingement on high furnace loads.

The operation of the crude residue system, as designed, was also unsatisfactory. Originally, the fuel-oil bottoms from the " A " and " B " columns flowed to a buffer tank, which was blanketed by CO_2 to prevent spontaneous ignition by contact of the hot oil with air. The residue was then pumped from this vessel by a turbine-driven centrifugal pump to storage through the reboilers of the gasoline-stabilizer system, the crude-oil heat-exchangers, and the fuel coolers. Very slight gassing of the charge to this pump caused gas locking, and re-establishment of suction was extremely difficult. During the period of commissioning of the unit, such gas-locking troubles were frequent, largely because on each occasion that the unit was being brought back on to line after a shut-down for alteration, certain parts of the equipment still contained water derived from the steaming out, sufficient to cause the column bottoms to froth. This gas locking, if prolonged, caused the buffer tank to overflow hot fuel oil, with the attendant risk of spontaneous ignition in addition to the hazards from scalding.

The problem was solved by the elimination of the buffer tank from the system, the pump being connected to take suction directly from the bottoms of both " A " and " B " columns. As the pressures obtaining in these columns were not equal because of the different sizes of the columns and the different pressure drops across the overhead vapour systems, separate level-control systems were installed on each column, as previously described.

Because of the stringent time factor, the columns for this plant were not cleaned before starting up the unit. Cleaning them is very difficult, because the column heads are welded to the shell, and all trays have to be dismantled and removed via four manholes in the side of the column. As

it happened, " A " column would handle little liquid load, and had to be cleaned forthwith : " B " column was capable of carrying its liquid load, but scale was sufficiently abundant to interfere frequently with the gravity run-off of the sidestream.

Originally two columns had been included in the stabilizer system, but " C " column, now idle, was choked so badly that it could not be used at all as a fractionator, and the stabilizer charge was merely pumped through it to the " D " column (the present stabilizer column). The " B " and " D " columns were both cleaned at the first opportunity.

The original redesigning of the stabilizer system involved the provision of reboiler heat by the hot fuel oil from the crude columns. It was realized at the outset that this would require modification, since the heating system was known to be inadequate to permit the stabilization of all gasoline production when all three plants were running. At a later date, therefore, the stabilizing system was redesigned to use " D " column only and to use high-pressure steam at 290 p.s.i. as the heating medium. This latter change also had the advantage that the stabilizer could operate as a separate entity from the rest of No. 3 distillation unit.

At the outset it was doubted whether the proportioning of the heated crude between the " A " and " B " columns could be achieved successfully by simple hand-throttling of the streams to the two columns, at the same time preserving the same ratio of vapour to liquid in the divided feeds. As the loading of both columns was rather high, any serious malproportioning of the liquid and vapour portions of the feed would have been expected to lead to serious overloading of one of the columns. Originally, therefore, a drum was provided in the transfer line of No. 3 unit for the separation of liquid and vapour portions of the heated crude, and automatic control of the flow of both the separated liquid and vapour portions was arranged to both " A " and " B " crude-distillation columns. This somewhat complicated system was never commissioned, as it was found that by running the drum full of liquid satisfactory operation could be obtained by hand-throttling using only the vapour outlets from the drum. Hence no vapour-release drum was provided for No. 2 unit, but on that unit simple hand-throttling was not satisfactory, there being a preponderance of the liquid portion of the feed in the charge to " A " column. This was subsequently corrected by the installation of the horizontal Y-piece already described.

Finally, one of the most puzzling of the difficulties encountered was found to have the simplest cause. Many attempts to commission the compressor delivering the rich gas to the stabilizer had been made and abandoned because of the quantity of liquid which was sucked into the compressor cylinders. Fortunately, on each occasion the compressor was shut down in time to prevent serious damage. The gas was known to be wet, and was passed through a bed of Raschig rings for mist extraction. This did not solve the problem, as the compressor cylinders still rapidly filled with liquid. After much fruitless investigation, it was discovered that a long section of the compressor suction line did not slope towards the compressor, as visual inspection indicated, and hence was never drained of liquid. On starting the compressor, this slug of liquid was drawn over into the compressor suction. The condition was corrected by the installation of new and adequate drains.

Catalytic Treating Plant.

When the refinery had been in operation for only two months, and before all three distillation units were in operation, it became necessary for Heysham to accept cargoes of Iraq crude. This increased the difficulty which had been experienced in the simultaneous attainment of gasoline with a sufficiently high octane number and gas oil with a specification flash point. The chief difference between Kuwait and Iraq crudes responsible for this operational difficulty in that, whereas both crudes have a similar sulphur content, the sulphur in Kuwait crude is largely concentrated in the heavier ends, whereas in Iraq crude there is a higher proportion of the total sulphur content in the lighter ends. This had the result that the gasoline prepared from Iraq crude had a higher sulphur content, and hence a lower lead susceptibility, than that prepared from Kuwait. So much so, in fact, that it was found impossible to meet the necessary octane number of the gasoline with 1·8 cc T.E.L/I.G. while making gas oil with a flash point of 150° F.

The difficulty was temporarily overcome by importing higher-octane gasoline for blending with the Heysham product to meet market requirements. The disadvantage of this procedure was that, as will be seen later, the ocean jetty was fully occupied with the importation of crude, and it was extremely difficult to arrange shipping programmes to include this additional demand upon the time available at the jetty. It was imperative, therefore, to discover a method of improving the quality of Iraq gasoline, and the obvious mode of approach lay in some sort of desulphurization.

The *iso*-octane plants at Heysham were idle, and the dehydrogenation section had attractive possibilities for catalytic desulphurization. Experimental work was, therefore, put in hand to determine whether it was possible to desulphurize Iraq gasoline over a variety of catalysts, including the British oxide, which was already in place in the dehydro reactor. These experiments were attended with sufficient success to justify a full-scale experiment, and the dehydrogenation section of the north *iso*-octane unit was modified to suit its new function. The revamping of the plant was completed at the end of November 1948, and by this time it had been decided that no more Iraq crude would be imported at Heysham, but, at about the same time, the specification for the lead content of Heysham gasoline was reduced from 1·8 to 1·5 cc T.E.L/I.G., and the experiment was continued with Kuwait gasoline, because the pilot-plant work had shown that, in addition to the desulphurization of Iraq gasoline, there was also some octane improvement due to reforming.

A part of the stabilizer feed is by-passed from the stabilizer charge line and constitutes the feed to the catalytic treating unit (Fig. 8). After treatment, this gasoline is returned to the stabilizer charge line.

The gasoline for treatment is fed, without heat exchange, to the old butane heater, which is a down-fired equiflux heater arranged in two cells, each with two separate banks of convection and radiant tubes, there being twenty-one convection and thirteen radiant tubes in each bank. The heater is fired with forty steam-atomizing oil-burners. The flow of gasoline through the four parallel streams is controlled by flow controllers. The firing in each of the two cells of the heater is on automatic control by means of a temperature-controller recorder on the gasoline vapour outlet. The

gasoline vapours leave the heater through a transfer line and pass to the inlet switch-valve manifold of the dehydrogenation reactor. By means of this manifold, either gasoline vapour or reactivating gas can be fed to either of the two halves of the reactor. The reactor consists of 576 tubes, which are arranged in four cells, there being two cells in each half. The tubes are vertical, 15 ft long × $2\frac{7}{8}$ in internal diameter. The catalyst, in the form of $\frac{1}{8}$-in cylindrical pellets, consists essentially of 10 per cent chromium and 90 per cent aluminium oxides, and is supported in the tubes on ceramic balls. The depth of catalyst in each tube is 14 ft 2 in. The tubes are heated externally by circulation of the hot products of combustion from a Dutch-oven type of furnace direct-fired with steam-atomiz-

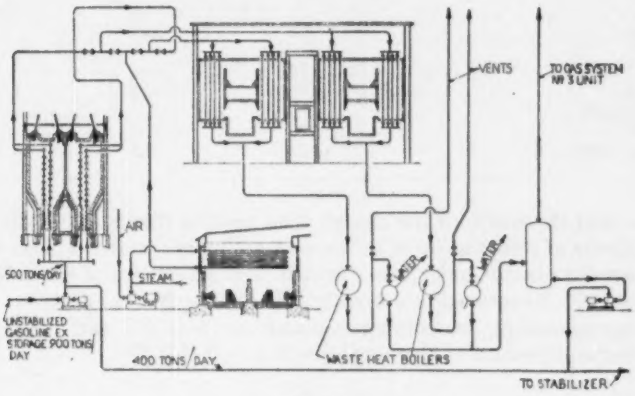

FIG. 8.

CATALYTIC GASOLINE UNIT.

ing oil-burners. The hot flue gases are circulated in firebrick ducts round the outside of the tubes by means of a fan driven by a 125-h.p. electric motor.

The hydrocarbon vapours leave the reactor tubes through a collecting header and flow to waste-heat boilers, of which there is one for each of the two banks of the reactor. The partly condensed reformate is further cooled in water-coolers, one for each bank. The cooled reformate liquid and gas flow to a receiver in which separation takes place. The liquid reformate is then pumped back into the feed line of untreated, unstabilized gasoline, and is charged therewith to the stabilizer column. The reformate gas passes to the refinery rich-gas system, and is charged with the saturated rich gas also to the stabilizer column. Approximately 2 per cent of the gasoline is degraded to gas. The capacity of the plant is approximately 550 tons per day, and while operating on Kuwait gasoline the octane number of the product, when leaded with 1·5 cc T.E.L/I.G. is six or seven numbers higher than that of the feed under the same conditions.

A certain amount of carbon is put down on the catalyst during the reaction, necessitating periodic catalyst reactivation. The reactivating gas consists of steam with the addition of about 2·2 cu. ft. of air (measured at N.T.P.) per lb of steam, pre-heated in the original reactivating gas-

heater to a temperature of about 500° C. The heater is a convection type of up-draught heater with the flow arranged in eight parallel streams; there being eight rows of eight tubes each. The tubes are all 4-in dia, 20 ft long, but those in the top row are finned. It has been found necessary to reactivate the catalyst every 48 hr, one bank being isolated for this

TABLE VI.

Average Plant Operating Conditions (Catalytic-treating Unit).

	Pressure, p.s.i.	Temp, ° C.	Flow.
Feed	—	—	570 tons/day
Heater:			
Inlet	75	12	—
Outlet	44	540	—
Reactor:			
Inlet	42	495	—
Outlet	22	555	—
Waste-heat Boiler:			
Outlet	20	170	—
Cooler outlet	18	40	—

purpose, and the whole of the charge then passing through the other bank. The products of combustion of the carbon are blown to atmosphere through a vent on the reactor-oulet line situated just up-stream of the inlet to its water-cooler. Reactivation normally takes 12 hr to complete.

Average operating conditions are shown in Table VI, and the properties of the feed and products before stabilization in Table VII.

STORAGE AND DISTRIBUTION.

The preceding account has dealt exclusively with plant alterations at Heysham. A very considerable amount of work was also necessary to fit the storage and distribution facilities for their new functions. During the war, aviation gasoline had left Heysham by road, rail, and sea, the latter mode of delivery being effected at a berth on the north wharf of Heysham Harbour. The facilities used for these three methods of delivery were sufficient to deal with an average intake to the factory of 1500 tons a day. The problem that had to be solved was to obtain delivery facilities for an average total production of 4500 tons per day. Under ordinary peace-time distribution there is a limited amount which can be distributed by road and rail, this limit being imposed by the distance from the refinery to which it is economic to distribute by these methods. Owing to the situation of Heysham in a non-industrial part of the country, the amount of gasoline, gas oil, and fuel oil which could be distributed economically by road and rail was such that the majority of these products remained to be distributed by sea. So far as road and rail distribution is concerned, arrangements were fairly simple.

The finished gasoline is all stored in part of the tanks situated at the adjacent Aviation Fuel Reserve Depot. This depot was already equipped with both road- and rail-loading gantries sufficient to handle the anticipated traffic in gasoline.

TABLE VII.

Properties of Feed and Products of Catalytic Treating Plant.

	Products before stabilization.		
	Feed.	Reformate.	Gas.
Sp. gr. at 60°/60° F	0·707	0·712	—
Bromine No.	0·1	10	—
Aromatics, % wt	8·5	9·4	—
Existent gum, mg/100 ml	Nil	2·4	—
Vapour pressure (Reid) at 100° F, p.s.i.	11·6	10·4	—
Octane No. + 1·5 cc T.E.L./I.G.	66	72	—
Distillation of A.S.T.M.:			
I.B.P.	31	33	—
5 per cent vol recovered at ° C	51	52	—
10 " " "	60	61	—
20 " " "	76	76	—
30 " " "	90	89	—
40 " " "	101	100	—
50 " " "	112	110	—
60 " " "	120	119	—
70 " " "	132	128	—
80 " " "	141	138	—
90 " " "	153	149	—
F.B.P., ° C	171	170	—
Residue, % vol	1·0	1·0	—
Loss, % vol	4·0	2·5	—
L.T.R. Analysis:			
Hydrogen, % wt	—	—	0·91
Methane, % wt	—	—	4·84
Ethane, % wt	—	—	5·75
Ethylene, % wt	—	—	6·58
Propane, % wt	0·16	0·56	14·90
Propylene, % wt	—		8·68
*iso*Butane, % wt	1·03	3·98	5·58
n-Butane, % wt	5·73		18·20
Butylenes, % wt	—	1·07	5·58
Pentanes, % wt	11·47	11·15	23·40
Hexanes and heavier, % wt	81·61	83·24	5·58

The bulk of the gas oil is also stored in the remainder of the tanks at this depot, but is not distributed therefrom either by road or by rail. The rail distribution is effected from one tank in the finished products tank farm, using a part of the large rail-loading gantry which already existed there. The remainder of the gantry is used for rail loading of fuel oil, and it is pumped to this gantry direct from one of two 5000-ton storage tanks inside the refinery, which are also the fuel-oil rundown tanks. The pipeline used for this purpose is 3700 ft long, and in order to prevent solidification of the fuel oil in cold weather it is possible to return fuel from the gantry back to the rundown tank by a second line.

Road loading of both gas oil and fuel is effected from a four-point gantry, which has been erected inside the refinery site, deliveries being made direct from the respective rundown tanks.

It was in the sea distribution of products that the major problem lay. In the first place, the ocean jetty has only one berth, and hence can accommodate only one tanker at a time. The majority of crude vessels arriving

at Heysham are of the T.2 type, and each vessel brings some 15,000 tons of crude oil. Berthing at the jetty can be effected only at low slack water, and largely for this reason each vessel occupies the berth for two days. Thus it takes two days to import the quantity of crude which the refinery can process in three days. The situation is further aggravated by the unprotected position of the jetty, which renders it absolutely at the mercy of rough weather. It can be seen, therefore, that with the ordinary interference to which shipping programmes are prone, added to the interruptions which the use of the jetty sustains from rough weather, the necessity for using the jetty for crude importations two days out of three means that almost the whole of its useful time is occupied in the importation of crude.

At the outset, when British Railways were approached for permission to export products by means of berths in Heysham Harbour, it was categorically stated that the export of gasoline could not be permitted because of the fire hazard, with consequent interruption to the railways' normal freight and passenger traffic to Ireland. It was, therefore, essential that the sea export of gasoline should take place at the ocean jetty, and this use of the jetty, in addition to its main function for the import of crude, made it quite impossible to consider it for the export of any other product. During wartime there was only one berth available for oil traffic in the harbour, and British Railways stated that they could not consider the freeing of any further quay space for the purpose, since every other inch of harbour wall, other than the oil berth on the north wharf, was essential for their own traffic. A portion of the north side of the harbour, however, had never been made into a proper quay, and consisted of a sloping pitched stone wall. British Railways stated their willingness to permit the construction of a proper berth at this situation. The time factor, however, rendered the building of a stone wall in the harbour impossible. The difficulty was overcome by placing a pontoon in the harbour opposite the sloping wall. (As a matter of interest, the pontoon was a Mulberry Harbour pierhead and saw service at Arramanches.) It was held off from the wall by steel booms, which are set in swivels at either end so that the pontoon can rise and fall with the tide. There is also provision for lateral movement which is restrained by heavy mooring chains. One of the booms carries a walkway and all necessary pipelines, cables, etc. This portion of the harbour, which had a depth of only 14 ft, was dredged to equal the depth of 17 ft in the remainder of the harbour and, further, the actual berth area at the pontoon was dredged to a depth of over 21 ft so that a vessel of 3000 tons capacity could remain at the pontoon in a loaded condition at the lowest tides.

Gas oil is loaded at the two berths in the harbour by pipeline from the tanks in the Aviation Fuel Reserve Depot.

Fuel oil is pumped from the large refinery rundown tanks into four of the 5000-ton tanks in the crude-oil farm, which were steam-coiled for this purpose. From these tanks the fuel is loaded at the two berths in the harbour. This necessitated the provision of additional pumping facilities in the crude-oil tank farm.

Two Lancashire boilers were transferred from another refinery and installed, together with all necessary ancillary bunker and feed-water facilities. Four pumps were provided : two 18 in $\times$ 10½ in $\times$ 24 in are permanently in fuel service and two 14 in $\times$ 12 in $\times$ 24 in can be used either for fuel service

or for crude as standby for the electric pumps normally used for crude transfer to the refinery.

Facilities have also been installed in the harbour area so that vessels

TABLE VIII.

Average Properties of Heysham Products.

	Motor gasoline.	Gas oil.	Fuel oil.
Sp. gr. at 60°/60° F	0·708	0·821	0·944
Vapour pressure (Reid) at 100° F, p.s.i.	9·7	—	—
Doctor test	Negative	—	—
Sulphur (lamp), % wt	0·02	—	—
Octane No., C.F.R.(M.M.)	57	—	—
Octane No. + 1·5 cc T.E.L/I.G.	70	—	—
Gum existent, mg/100 ml	2	—	—
Viscosity Redwood I at 100° F, sec	—	32	900
Flash point, P.M., (closed) ° F	—	164	250
Pour point (max), ° F	—	<0	+30
Ash, % wt	—	<0·01	<0·01
Carbon residue (Conradson), % wt	—	0·01	—
Sulphur (quartz tube), % wt	—	0·8	3·4
Distillation A.S.T.M.:			
I.B.P.	34	196	—
5 per cent vol recovered at ° C	48	—	—
10 " " "	56	213	—
20 " " "	70	221	—
30 " " "	84	231	—
40 " " "	96	239	—
50 " " "	109	249	—
60 " " "	119	260	—
70 " " "	130	274	—
80 " " "	142	294	—
90 " " "	154	316	—
95 " " "	166	341	—
F.B.P., ° C	171	364	—
Residue, % vol	1·0	1·0	—
Loss, % vol	2·0	Nil	—

may pump oily ballast ashore, where separation can take place, the clean water being run back into the harbour.

The average properties of the products made at, and distributed from, Heysham are shown in Table VIII.

ACKNOWLEDGMENTS.

In conclusion, the author wishes to acknowledge his gratitude to the "Shell" Refining and Marketing Co. Ltd., for permission to publish the subject-matter of this paper, and to the staff of the Heysham refinery for much valued assistance and criticism in its preparation.

DISCUSSION.

THE PRESIDENT: We have heard a very fascinating story. We are fortunate also in having with us gentlemen who are quite distinguished in the refining field, and we look forward to some interesting contributions from them.

C. A. P. SOUTHWELL : I congratulate Mr Kirby on the very excellent paper which he has delivered. I am particularly interested in view of my association with the development of the petroleum resources of Kuwait, from whence the crude is produced and shipped to Heysham.

I feel sure that the paper has stimulated a number of questions which those connected with the refining side of the industry would like to ask, and I do wish not, therefore, to take up any more time. There is, however, one item on which Mr Kirby has touched which is of considerable interest. He mentioned the installation on Heysham pier of the Baker fenders. Many members may not know that the Baker fender was invented by Prof. Baker for the Mulberry Harbour pier-head. As far as I am aware these fenders have only been used in the Mulberry Harbour, the Heysham refinery pier, and in Kuwait. In Kuwait they are large-sized fenders and are giving excellent service, enabling ships to be docked with the minimum of difficulty, and saving the oil-pier itself from damage. I hope that this important marine side of the oil industry will be the subject of a discussion before the Institute at some future date.

J. S. PARKER : Although I come from quite close to Heysham I have never seen the Heysham refinery, either as it was originally or as it is now. I have, however, knowledge of it as I have seen its twin in full operation at Curaçao. Erection of the twin at Thornton, Ellesmere Port, proceeded during the early days of the war, but for one reason or another this project was abandoned and the complete unit shipped to Curaçao.

These units were specialized jobs, and consequently their transformation to normal distillation practice was by no means a simple project. It has been of interest to note how this was done and the remarkably short time required to do it. Besides plant difficulties there was a swing to a different type of raw material with high sulphur content. It would be interesting to know if any provision was made to combat corrosion, which might arise in certain items because of this sulphur content.

In skimming over the preprint I noted that Heysham got away with 1·8 cc of T.E.L. against a specification limit of 1·2 cc, but Mr Kirby has explained my query on this point during his lecture.

The paper is one of these which is more or less a statement of fact, and consequently there is little which one can talk about or criticize. It has been presented in a most excellent fashion, and I would congratulate Mr Kirby on it.

E. J. DUNSTAN : Mr Kirby has dealt with a subject which is a little outside my territory; but I must say I am rather pleased to note that, in spite of almost universal standardization in this country to-day, there are signs that ingenuity does still exist ! Of course, when listening to Mr Kirby discussing the difficulties he encountered, one is inclined to think that they should have been forseen; but I am sure that Mr Kirby would have been equally as wise as he has made us if before he had started on the plant he could have heard what he has told us this evening.

The job was done extraordinarily quickly. One heard one day that the Shell organization had acquired the property; then there was a pause, then products began to flow out, and eventually we have heard the story.

It would be true to say that what has been done is just what we should have expected from Shell; but this extremely interesting story shows what can be achieved if there is the desire and the drive to achieve it, and the whole thing can only reflect glory on everybody connected with it.

E. C. MASTERSON: Speaking as a field man, I was surprised to hear that it is possible to process crude oil in a simple distillation unit in such a way as to yield only three products, namely unstabilized gasoline, gas fuel, and fuel oil. I was under the impression that including the greater part of the kerosine cut in the gas oil would spoil the flash of the latter.

I would be glad if the speaker could indicate what percentage of gasoline was taken from the main tower, and indicate what proportion of this overhead cut was passed through the catalytic-treating plant.

Mr Kirby pointed out in his paper that the octane number of the gasoline was improved by about six points, subsequent to putting the catalytic unit into operation. Does this mean that the octane number of the whole make of gasoline was improved by six points, or only that portion which was passed through the catalytic plant?

DR G. B. MAXWELL: I would like to ask two questions, one of them in connexion with the gasoline. At what sulphur content are you running, both on the final stabilized product, *i.e.*, that which has been subjected to the catalytic treatment, and on the untreated material?

Secondly, I was interested that you broadened the range of your distillation cut from the gas-oil, presumably to meet the viscosity specified on. Did you experience any difficulty in meeting the carbon-residue specifications by cutting deeper?

E. THORNTON: This is a paper to gladden the hearts of all refiners. What cheers me is, that in this particular instance at least, the plant did run for a short time and achieve what it was designed to achieve.

With regard to this ingenious method of increasing turbulence by coring, did you experience any difficulties in dealing with the hard cores in the tubes? The conditions are sometimes not turbulent without cores, but I would be interested to know what happened with regard to them.

A. D. DAVIDSON: You have mentioned the difficulties you experienced with the residue pumps due to gas locking when taking suction from the buffer tank. To overcome the trouble you took suction in the bottoms of the columns, presumably obtaining a higher net positive suction head. What was the net positive suction head when you were taking suction from the buffer tank? If the pumps were of English design it is quite probable that they could have operated with a low net positive suction head, whereas with American-designed pumps one would have expected the difficulty that was experienced. It would be interesting to know, especially in view of the fact that so many pumps now are made to American patterns in this country.

Secondly, what was the difference between the temperatures at which you desulphurized Iraq stock and Kuwait stock? Did the temperature increase when you wanted to reform the Kuwait stock?

A. C. McGechan: This question follows from two earlier ones. It would be very interesting to hear Mr Kirby's experience of the materials used, especially in the catalytic reactors. The later conditions using high-sulphur crude were presumably not anticipated in the original design. Was the same material still used, and what was the experience with it?

J. S. Parker: The particular method of catalytic desulphurization used at Heysham is new, and it would be of interest to know the economic side of it. If there had not been the obvious restriction which had limited them to this method, would they have projected along similar lines, or would they have installed another probably more economic method.

R. A. Fraser: I have not read the paper by Mr Oriel and Mr Gordon on the operations at Heysham during the war; but perhaps Mr Kirby could answer my question. Was Victane (butyl benzene) produced at Heysham and, if so, what was the process used?

C. Paysant: You have told us what you did finally at Heysham. I am wondering what factors influenced you in planning the carrying out of the processes in the installation. It seems to me that there are a number of alternatives, and it would be interesting to hear what reasons took precedence in planning the installation as it is planned.

E. J. Dunstan: I should like to know at what point the gasoline was cut in the case of the Kuwait and Iraq products in order to obtain the final gasoline with lead at 1·8 cc per Imp. gal.

H. T. Lorne: I have not been able to read the paper yet, but I should like you to tell us what were the intermediate and finishing treatments that were being employed on the gasoline. I can see that you have had trouble in respect of the lead response of the gasoline.

Mr Kirby (replying to the discussion) said:

With regard to the fenders at the pier, the subject is too big to deal with now, especially as I have no pictures available. As has been suggested I think it would be preferable to wait until more time can be given to the subject.

I am sorry that I have omitted to mention the corrosion difficulties which we experienced. We found it very necessary to inject ammonia into the vapour lines of the primary distillation columns and of the two gas-oil strippers. The materials generally in the distillation units are quite conventional; but in one or two cases where the condensers had had arduous duties during their previous use we found that the vapours fairly quickly corroded through the bottoms of the shells. This was overcome by providing the shells with a monel-metal lining.

I do not think there is really any difficulty with regard to the lead concession that we were given, but one point should be clarified. It is quite true that the specification was 1·2 cc T.E.L. per gallon. This in fact refers to a U.S. gallon but all the figures otherwise quoted this evening are per Imperial gallon. The specification is equivalent to 1·5 cc T.E.L/Imp. gal.; thus, the concession granted was not as great as might appear.

As to the speed of conversion, Heysham is situated in a district where skilled engineering labour is scarce. The necessarily large crew of engineering workers essential for the urgent work we had to do was obtained by borrowing from the Shell refinery at Stanlow. At its peak this crew numbered some 240 men, whose work approximated to 12-hr days and seven-day weeks. We had stated originally that we would have the first unit running in four weeks from date of purchase; we actually started up in five weeks. We also stated that the whole refinery would run at a daily intake of 4500 tons in four months from the date of purchase; this object was achieved. The much smaller crew for running maintenance was locally recruited.

The yield of gasoline was approximately 17 per cent of the crude, and of that quantity half was given the catalytic treatment. The improvement of 6 to 7 octane numbers relates to the portion which was treated, the comparison being between the octane number of the feed to the catalytic unit with 1·5 cc T.E.L/Imp. gal. and the octane number of the product from the unit leaded to the same extent. The sulphur content was about 0·02 per cent in the case of the Kuwait gasoline. There was only a small difference between the sulphur content before and after treatment, the bulk of the octane-number improvement being derived from the reforming effect rather than from desulphurization. Iraq gasoline was run only for such a short time that reliable figures were not established, but there was an appreciable reduction of sulphur content.

We did not have any serious difficulty with the cored furnace tubes, and were able to remove some cores after they had been in place for a short time. We did not, however, run with them long enough to decide whether or not it would be difficult to withdraw cores from badly coked tubes.

In answer to the question about the positive suction heads to the residue pumps, we had a head of 8 to 10 ft while drawing from the accumulator vessel and of some 15 ft while taking direct suction from the columns. In my opinion our troubles were not so much due to inadequate head as to the fact that our initial attempts to get the plant into operation were fairly frequently interrupted. There were furnace difficulties and a variety of other troubles all of which entailed shutting down the plant and steaming out. Our difficulties were probably largely due to traces of water remaining in the system from the previous steaming out. Nevertheless, the original arrangement was not satisfactory, and obviously required alteration.

The temperature in the catalyst tubes of the treating unit was about 550° to 560° C, and was the same whether we were running Iraq or Kuwait gasoline. The catalyst tubes are the same as had seen service during the war, and were constructed of 27 per cent chromium steel. They had proved quite satisfactory in their original job and are also eminently satisfactory now, but the conditions at present are vastly different from those necessary for butane de-hydrogenation in that the temperature of the flue gases circulating around the outside is very much lower.

We do not claim that our catalytic treatment of gasoline is a particularly attractive economic proposition, but it arose from that necessity of making do with what we had, which influenced so many of our decisions. The position is that we are putting a part of the full range gasoline fraction through the treatment, whereas the light fractions up to an E.P. of 100° C

have a relatively good octane number and do not really need treatment. It was impossible at the time for us to make provision for separating two gasoline fractions and treating the heavier portion only, but plans are now afoot to do so.

Victane was never produced at Heysham.

With regard to our plan and the factors influencing our decisions, the main consideration was the achievement of maximum throughput with the equipment available. Thus, if a plant were short of heating capacity we found another heater. If another plant were short of fractionating equipment we used two columns in parallel. Almost all the plants were short of heat exchangers which were obtained from one of the *iso*-octane units for which no plans had been envisaged.

The cut points of the gasoline made from Kuwait and Iraq crudes were not very different. The important consideration was to obtain a gas oil with a flash point which satisfied the specification, because if the flash point was not high enough there was no corrective action which could be taken. On the other hand, the problem of gasoline quality could be approached in a variety of ways. In effect we made the gasoline which we obtained when making our gas oil with an adequate flash point.

There was no elaborate equipment available for the chemical treatment of gasoline, but the aviation gasoline produced during the war had been given a simple soda and hypochlorite treatment to make it doctor sweet. The same equipment and the same treatment was found to be adequate for our motor-gasoline production.

Vote of Thanks.

The President : Shortly after the war I was frequently asked by my many automobile-engineer friends whether the time was now ripe for designing and making motor-car engines suitable for using 100-octane fuel. You can imagine their disappointment when they found it was nearer 70-octane. Consequently, some began to wonder what had happened to all our wonderful plant. To-night we have heard the secret. We have been told in a very amiable and convincing way by Mr Kirby how the great problems of conversion have taken their course. I think the fact that those responsible made this enormous conversion within five weeks after entering on the site is something which will startle perhaps some of our American friends. Obviously many difficulties were met; but Mr Kirby has so simplified those difficulties that it is hard to realize that they ever existed. Some of the difficulties which he has explained must make us feel a little alarmed, as, for instance, when he talked about the bowing of the tubes containing such an inflammable fluid as petroleum.

It is perfectly evident from the discussion that you have all enjoyed very much indeed this fascinating epic which Mr Kirby has unfolded, and it is my pleasure to offer him, on behalf of the Institute of Petroleum, our very warmest thanks for the effort he has put into the preparation of the paper, and for having travelled from Heysham to give us this very delightful evening.

(The vote of thanks was accorded with enthusiasm).

THE MAGNETO-OPTICAL ROTATION OF PURE HYDROCARBONS AND ITS APPLICATION TO THE ANALYSIS OF MIXTURES.

By J. B. WESTERDIJK, H. I. WATERMAN (Fellow), H. F. O. SPAN, H. BOOY, and K. VAN NES.

SUMMARY.

The results of measurements of the Faraday-effect of pure hydrocarbons by Foehr and the authors are discussed. As might be expected from theoretical considerations, different structural groups of a molecule contribute additively to a constant D, which is a function of the measured Verdet-constant and other physical properties of the substance. This additivity does not hold for the contributions of ramifications, which are irregular. This means that the constant D cannot be safely used in structural group analysis if one is especially interested in the number of side-chains of the average molecule in a mixture of hydrocarbons. In this case, however, the Verdet-constant itself may give useful information about the number of ramifications. This is shown only for alkanes with side-chains, as the number of naphthenes of which the Verdet-constant has been determined is too small to justify definite conclusions, although the results are promising.

It is shown that the constant D is a linear function of the square of the frequency of the light source if this frequency is sufficiently-far removed from the range where absorption occurs. Measurements of the dispersion of the Faraday-effect should therefore be not very interesting from an analytical point of view.

The authors are convinced that measurements of the magneto-optical rotation may in future be regarded as belonging to the useful methods of determining the structure of the average molecule in hydrocarbon mixtures, especially in the range of low molecular weight.

INTRODUCTION.

DURING recent years one of the authors and his collaborators have published several papers [1] on the structural group analysis of mineral oils, by means of measurements of physical constants—such as density, refractive index, (average) molecular weight, etc.—and functions of these constants. They used, for instance, the specific refraction, which is an additive property because it may be written as the sum of the products of concentration and average group contribution of the structural groups present in the mixture. Recent development of the original "Waterman ring analysis" led to the *n-d-M* method, which aims at the determination of carbon distribution, *i.e.*, the percentage of carbon present in aromatic, naphthenic, and paraffinic structure respectively, and ring content, *i.e.*, the average number of aromatic and naphthene rings per molecule. Although these methods for structural group analysis have proved very useful in the oil industry, they give no information about the way in which structural elements are linked together.

In 1941 the present authors, in collaboration with E. C. Wiersma and S. Broersma, started the investigation of the magneto-optical rotation of

pure hydrocarbons and well-defined mixtures, hoping to find in the measurement of the Verdet-constant a means of pushing the structural group analysis further than had hitherto been possible. It was shown,[2] that, whereas the Verdet-constant itself cannot be regarded as a purely additive constant, a constant D, which is a function of the average molecular weight, density, refractive index, and Verdet-constant, possesses, as might be expected from theoretical considerations, the additive properties which enable us to use it in statistical analysis. Moreover, this constant D showed itself quite independent of temperature over a wide range, so that data on highly volatile substances and on samples with a high melting point are as such comparable.

The additive character of the constant D, however, does not hold for hydrocarbons containing one or more ramifications, as the contribution of a ramification to the total value of D shows irregularities greater than the error of the measurements. Their contribution to the Verdet-constant itself, however, seemed to be additive to a high degree, a fact which cannot be easily understood, and which was not published at the time, as the number of pure hydrocarbons investigated by the authors was too small to justify conclusions.

In 1948 a thesis, written by Foehr [3] appeared, in which the results of measurements on a large number of pure hydrocarbons, many of them of high molecular weight, were described. Foehr's results and those of the authors were generally in very good agreement. Recently a paper was published by J. Tadayon, A. H. Nissan, and F. H. Garner [4] in which our values were compared with determinations of these British authors.

In the present paper the combined results published in references 2 and 3 will be discussed. It will be shown that the constant D has an additive character, even for more complicated structures, if substances containing ramifications are not taken into account, and that in the case of substances containing ramifications, the Verdet-constant proves to have additive character, which enables one to derive from measurements of this constant the number of ramifications present in the average molecule of a mixture, if the other structural properties, as determined by the methods described in reference 1, are known. This means that, in the future, the determination of the Verdet-constant may be a useful means to enlarge our knowledge of the constitution of mineral-oil fractions.

Apparatus.

If a column of liquid of the length l is placed in an homogeneous longitudinal field H, the plane of polarization of polarized monochromatic light passing through the liquid is rotated over an angle α. In this case a simple formula

$$\alpha = VHl \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

holds, in which the proportionality factor V is called the Verdet-constant. It depends on the constitution of the liquid and on the frequency of the monochromatic light. Its change with temperature is of the same magnitude as the change of density. A sodium discharge tube is commonly used as light source; measurements at other wavelengths than those of the

sodium D lines will be discussed. As standard temperature both Foehr and Fenske and the present authors chose 20° C.

In reality a magnetic field will never be constant over the whole length of a measuring tube; Eq. (1) must then be written $\alpha = V\int Hdl$, in which the integral stands for the magnetic potential difference between the ends of the tube. If a solenoid is used to generate the field, and the geometry of this coil, the position of the sample tube, and the current through the coil are known, the potential difference may be calculated. Instead, the coil may be calibrated by making measurements on substances the Verdet-constant of which is known accurately, or the Verdet-constant may be compared directly with that of a standard substance; this can be done in a double-coil apparatus. For their new apparatus the authors chose this last principle, as absolute measurements, as described in reference 2, require a more expensive electrical measuring bridge. As reference fluid water was chosen as the value of its Verdet-constant, which the authors measured in 1941 and which is in agreement within 0·1 per cent with the values found by others, may be taken to be accurate.

In 1948 a new apparatus was developed by one of the authors. This apparatus ensures the same high precision as the apparatus of 1941, but is easier to handle. It consists of two copper coils, which have been made as nearly identical as possible. These are wound in such a way, that oil can circulate between the successive layers of turns for cooling purposes. At an input pressure of 2 atmospheres the oil flows very rapidly, and turbulence is ensured. It enters each coil through eight radial slits cut into one of the end discs of the coil housing, and leaves through the other disc. It is then cooled in an automobile radiator placed in a water current from the mains. As soon as the oil flow drops below a minimum value the motor of the oil-pump and the current through the coils (about 25 amperes) are switched off by a safety device. In the centre of the solenoid a cylindrical jacket is mounted, which keeps the sample at the required temperature. It is fed from a large thermostat. The circuit also contains a storage box in which the samples to be measured may be kept at the temperature of 20° C. A constancy of temperature of about 0·01° C is necessary, as even slight gradients of the refractive index in the sample interfere with the focusing of the image in the polarimeter and so reduce the accuracy of the readings.

The polarimeter is of the Lippich half-shadow type. Polarizer and analyser are mounted on a very sturdy chassis; their distance is 80 cm. Between them the two magnetic coils are mounted in such a way that the sample tubes in both can be readily inserted and removed. One of the tubes is filled with the substance to be investigated, the other with pure water. The analyser is now turned into its zero position in which both parts of the field of view have equal brightness. The coils are then connected parallel to a big battery in such a way that their magnetic fields are opposed, and their respective currents are regulated until both parts of the field of view again show equal brightness. If the coils were exactly identical and showed no interaction, and if both sample tubes were of equal length, a very simple relation

$$i_1 V_1 = i_2 V_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

would hold, in which i_1 and i_2 denote the currents in the two coils, and V_1

and V_2 the Verdet-constants of the substances in the two sample tubes. In reality a number of small corrections must be made, mainly for the inequality of the solenoids, but this can easily be done experimentally.

If the Verdet-constant of one of the samples is known, the Verdet-constant of the other sample can be derived from Eq. (2) if the ratio $i_1 : i_2$ is known. As was mentioned before, we used water as reference substance; V_{H_2O} is $1{\cdot}309 \,.\, 10^{-2}$ min/gauss cm. It is always easier to determine a ratio of two currents than to measure an absolute value. The authors used a bridge method in which a precision of 10^{-4} is ensured. Thus the error of the determinations of V is wholly caused by the inaccuracy of the polarimeter readings. It is of the order of 0·1 per cent.

Results of the Measurements of Foehr and the Authors.

Before discussing the results of the different measurements, the authors will recapitulate some facts, published in reference 2. Some of their own results are revised.

(*a*) In general, the Verdet-constant has not additive character, whereas a constant D has. This constant is defined by

$$D = \frac{9nMV}{(n^2 + 2)^2 d} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

and may be written as

$$D = \sum_k a_k n_k \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

where the a_k denotes the contributions of the characteristic atomic groups or structural properties and n_k their number in the investigated molecule. This means that if, for instance, one plots the constant D of all normal alkanes over their molecular weight, a straight line results, as the contribution of each added CH_2 group is the same (this additivity will probably not hold for alkanes with less than four C-atoms).

A structural property of great interest is the number of ramifications in a molecule. It may not be expected, that each ramification in a substance as, for instance, 2 : 2 : 6-trimethyloctane gives the same contribution to any optical constant, as the first two ramifications are very near together, whereas the third is well outside the field of the others. Therefore it is not surprising that isomeres have different constants D. If, to simplify the picture, one takes only one mean value for the contribution of a ramification, deviations from additivity, which are not much smaller than the contribution itself, can occur.

(*b*) For mixtures one may write :—

$$D = \sum_k D_k c_k \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

in which the D_k are the constants D as measured on the pure components and c_k their relative molar concentrations. Eq. (5) holds for all mixtures of non-polar substances, and even in the case of polar mixtures, the deviations do not exceed 1·5 per cent.

(*c*) Although the Verdet-constant V of mixtures is not expected to be additive, an investigation of saturated hydrocarbons showed that the constant may be represented by a formula similar to (5), in which the c_t now denote the volume concentrations of the components.

TABLE I.

Magneto-optic Rotation and Other Constants of Alkanes.

Substance.	Author.	No. of C-atoms.	No. of H-atoms.	M.	d_4^{20}.	n_D^{20}.	B.p., ° C.	M.p., ° C.	$V_D^{20} \times 10^3$.	D_D.
n-Pentane	F	5	12	72·1	0·6260	1·3578	35·91	—	1·150	1·106
	W	5	12	72·1	0·6262	1·3576	35·95	—	1·149	1·095
2-Methylbutane	F	5	12	72·1	0·6190	1·3541	27·71	—	1·169	1·129
	W	5	12	72·1	0·6197	1·3539	27·80	—	1·174	1·133
n-Hexane	F	6	14	86·1	0·6591	1·3750	68·85	—	1·197	1·278
	W	6	14	86·1	0·6594	1·3749	68·75	—	1·197	1·279
2-Methylpentane	F	6	14	86·1	0·6536	1·3715	60·2	—	1·224	1·321
	W	6	14	86·1	0·6532	1·3715	60·30	—	1·223	1·322
3-Methylpentane	F	6	14	86·1	0·6641	1·3765	63·15	—	1·221	1·293
	W	6	14	86·1	0·6644	1·3766	63·30	—	1·218	1·290
2 : 2-Dimethylbutane	F	6	14	86·1	0·6487	1·3689	49·6	—	1·234	1·345
	W	6	14	86·1	0·6492	1·3688	49·70	—	1·242	1·353
2 : 3-Dimethylbutane	F	6	14	86·1	0·6619	1·3750	57·95	—	1·234	1·312
	W	6	14	86·1	0·6617	1·3750	58·05	−128·2	1·234	1·314
n-Heptane	F	7	16	100·2	0·6838	1·3877	98·42	—	1·229	1·459
	W	7	16	100·2	0·6838	1·3877	98·40	—	1·231	1·462
2-Methylhexane	W	7	16	100·2	0·6787	1·3849	90·10	−118·2	1·255	1·504
2 : 2-Dimethylpentane	F	7	16	100·2	0·6749	1·3820	79·15	—	1·273	1·538
	W	7	16	100·2	0·6789	1·3822	79·30	—	1·277	1·544
2 : 3-Dimethylpentane	F	7	16	100·2	0·6945	1·3916	89·8	—	1·265	1·475
	W	7	16	100·2	0·6951	1·3920	89·80	—	1·271	1·480
2 : 4-Dimethylpentane	F	7	16	100·2	0·6760	1·3821	80·6	—	1·280	1·544
	W	7	16	100·2	0·6728	1·3815	80·60	—	1·279	1·550
2 : 2 : 3-Trimethylbutane	W	7	16	100·2	0·6901	1·3895	81·00	—	1·297	1·524
n-Octane	F	8	18	114·2	0·7025	1·3979	125·6	—	1·254	1·640
	W	8	18	114·2	0·7028	1·3976	125·75	−56·8	1·261	1·649
3-Methylheptane	W	8	18	114·2	0·7058	1·3985	119·05	—	1·279	1·665
2 : 3-Dimethylhexane	W	8	18	114·2	0·7123	1·4012	115·80	—	1·296	1·668
3 : 4-Dimethylhexane	W	8	18	114·2	0·7195	1·4043	117·85	—	1·296	1·648
2 : 5-Dimethylhexane	W	8	18	114·2	0·6943	1·3928	109·25	—	1·296	1·722
2 : 2 : 3-Trimethylpentane	W	8	18	114·2	0·7161	1·4029	110·05	—	1·329	1·700
2 : 2 : 4-Trimethylpentane	F	8	18	114·2	0·6920	1·3916	99·30	—	1·331	1·775
	W	8	18	114·2	0·6920	1·3914	99·10	—	1·330	1·775
n-Nonane	F	9	20	128·3	0·7182	1·4065	150·75	—	1·279	1·841
	W	9	20	128·3	0·7181	1·4056	150·70	−53·7	1·284	1·836
n-Decane	F	10	22	142·3	0·7304	1·4146	174·2	—	1·306	2·024
	W	10	22	142·3	—	—	—	—	1·300	2·019
2 : 2 : 3 : 4-Tetramethylhexane	F	10	22	142·3	0·7551	1·4216	158·8	—	1·358	2·025
3 : 3 : 5-Trimethylheptane	F	10	22	142·3	0·7766	1·4230	161·5	—	1·356	1·964
n-Hexadecane	F	16	34	226·4	0·7743	1·4340	—	19·8	1·346	3·087
	W	16	34	226·4	0·7739	1·4346	—	17·9	1·359	3·118
2 : 2 : 4 : 7 : 9 : 9-Hexamethyldecane	W	16	34	226·4	—	—	—	—	1·454	3·324
7-*n*-Hexyltridecane	F	19	40	268·5	0·7878	1·4408	125·5*	—	1·374	3·655
5-*n*-Butylhexadecane	F	20	42	282·5	0·7909	1·4428	138·0*	—	1·383	3·850
9-*n*-Octylheptadecane	F	25	52	352·6	0·8017	1·4487	184·0*	−13·8	1·417	4·837
7-*n*-Hexyleicosane	F	26	54	366·7	0·8040	1·4497	193·5*	10·2	1·415	5·005
6 : 11-Di-*n*-amylhexadecane	F	26	54	366·7	0·8068	1·4502	181·5*	−16·2	1·423	5·014
11-Neopentylheneicosane	F	26	54	366·7	0·8029	1·4491	188·5*	−21·0	1·425	5·052
5 : 14-Di-*n*-butyloctadecane	F	26	54	366·7	0·8075	1·4508	185·0*	5·7	1·408	4·955
9-*n*-Octyleicosane	F	28	58	394·7	0·8074	1·4515	211·0*	0·5	1·415	5·358
7-*n*-Hexyldocosane	F	28	58	394·7	0·8078	1·4517	209·0*	19·3	1·413	5·247
9-*n*-Octyldocosane	F	30	62	422·8	0·8112	1·4537	222·5*	8·6	1·419	5·719
11-*n*-Decylheneicosane	F	31	64	436·8	0·8115	1·4557	229·5*	10·0	1·419	5·898
11-*n*-Decyldocosane	F	32	66	450·8	0·8127	1·4543	235·5*	—	1·412	6·054
11-*n*-Decyltetracosane	F	34	70	478·9	0·8164	1·4556	250·0*	10·8	1·415	6·410

Boiling point (b.p.) at 760 mm; if marked with an * at 1·00 mm.
Unit of the Verdet-constant V: min/gauss-cm.

The results of the measurements, both by Foehr and the authors, are represented in Tables I, II, and III. In these tables the values of the molecular weight M, the density at 20° C, the refractive index for the wavelength of the sodium D lines n_D, the Verdet-constant V, and the constant D are given. Moreover, the tables contain the melting points and boiling

points, which offer a good means of estimating the purity of the samples used by both authors. An *F* or a *W* in the second column denotes measurements by Foehr or by the present authors.

Table I contains alkanes with and without side-chains, Table II some naphthenes, and Table III aromatic compounds and other unsaturated substances. The values of *D* of substances investigated by Foehr have

TABLE II.

Magneto-optic Rotation and Other Constants of Naphthenic Hydrocarbons.

Substance.	Author.	No. of C-atoms.	No. of H-atoms.	*M.*	d_4^{20}.	n_D^{20}.	B.p., ° C.	M.p., ° C.	$I_D^{20} \times 10^4$.	D_D.
*cyclo*Pentane	F	5	10	70·1	0·7450	1·4065	49·25	—	1·229	0·925
	W	5	10	70·1	0·7454	1·4065	49·20	—	1·228	0·924
Methyl*cyclo*pentane	F	6	12	84·1	0·7490	1·4098	71·85	—	1·269	1·137
	W	6	12	84·1	0·7487	1·4098	71·85	−142·4	1·271	1·141
Ethyl*cyclo*pentane	F	7	14	98·1	0·7666	1·4197	103·5	—	1·296	1·314
n-Propyl*cyclo*pentane	F	8	16	112·2	0·7767	1·4263	131·0	—	1·313	1·496
*iso*Propyl*cyclo*pentane	F	8	16	112·2	0·7765	1·4260	126·5	—	1·327	1·513
n-Butyl*cyclo*pentane	F	9	18	126·2	0·7844	1·4313	156·6	—	1·331	1·683
2-*cyclo*Pentylbutane	F	9	18	126·2	0·7945	1·4357	154·4	—	1·345	1·674
2-*cyclo*Pentylpentane	F	10	20	140·3	0·7987	1·4393	176·4	—	1·364	1·872
2-*cyclo*Pentylheptane	F	12	24	168·3	0·8089	1·4451	219·0	—	1·374	2·225
11-*cyclo*Pentylheneicosane	F	26	52	364·7	0·8329	1·4613	198·5*	−12·7	1·432	4·822
1-*cyclo*Pentyl-4-(3-*cyclo*pentylpropyl)dodecane	F	25	48	348·6	0·8577	1·4707	193·0*	−40	1·441	4·473
1-*cyclo*Pentyl-2-hexadecyl-*cyclo*pentane	F	26	50	362·7	0·8594	1·4715	208·0*	18·7	1·436	4·626
1 : 7-Di*cyclo*pentyl-4-(3-*cyclo*pentylpropyl)heptane	F	25	46	346·6	0·8886	1·4829	198·0*	−23·7	1·491	4·402
*cyclo*Hexane	F	6	12	84·1	0·7792	1·4263	80·8	—	1·238	1·054
	W	6	12	84·1	0·7787	1·4098	80·80	—	1·238	1·056
9-*cyclo*Hexylheptadecane	F	23	46	322·6	0·8337	1·4620	168·5*	—	1·420	4·223
9-(2-*cyclo*Hexylethyl)heptadecane	F	25	50	350·6	0·8325	1·4614	188·5*	Gl.	1·424	4·612
7-*cyclo*Hexyleicosane	F	26	52	364·7	0·8367	1·4635	199·5*	Gl.	1·428	4·779
11-*cyclo*Hexylheneicosane	F	27	54	378·8	0·8373	1·4639	209·0*	−7·2	1·429	4·962
13-*cyclo*Hexylpentacosane	F	31	62	434·8	0·8390	1·4653	234·5*	1·2	1·434	5·698
Di*cyclo*hexyl	F	12	22	166·3	0·8860	1·4795	—	—	1·391	1·981
	W	12	22	166·3	—	—	—	—	1·397	1·985
1 : 1-Di*cyclo*hexylheptane	F	19	36	264·5	0·8830	1·4823	135·5*	—	1·432	3·248
1-*cyclo*Hexyl-3-(2-*cyclo*hexylethyl)hendecane	F	25	48	348·6	0·8657	1·4756	194·5*	Gl.	1·438	4·407
1-*cyclo*Hexyl-2-(*cyclo*hexylmethyl)pentadecane	F	28	54	390·7	0·8632	1·4747	214·5*	1·7	1·442	4·970
cis-Decalin	F	10	18	138·2	0·8971	1·4814	195·5	—	1·389	1·621
trans-Decalin	F	10	18	138·2	0·8719	1·4702	187·9	—	1·391	1·685
11-α-Decalinheneicosane	F	31	60	432·8	0·8697	1·4778	235·5*	Gl.	1·442	5·452

been calculated from his data by the authors. Most substances belong to one of the following types :—

(*a*) alkanes;
(*b*) monocyclic naphthenes;
(*c*) dicyclic naphthenes;
(*d*) phenylalkanes;
(*e*) diphenylalkanes;
(*f*) alkenes;
(*g*) diphenylalkenes.

The values of *D* of substances belonging to these types have been plotted against the number of C-atoms per molecule in Fig. 1. The result is a series of seven straight parallel lines, each corresponding to one of the types (*a*)–(*g*). Parallelity of the lines means that the contribution of a CH_2 group is the same for all types of molecules, as might be expected.

Deviations are mainly caused by ramifications; this is most clearly seen if one studies line *a*. The vertical distance between each of the lines *b* — *g* and line *a* represents the contribution of the characteristic group

TABLE III.

Magneto-optic Rotation and Other Constants of Unsaturated Hydrocarbons.

Substance.	Author.	No. of C-atoms.	No. of H-atoms.	*M.*	d_4^{20}.	n_D^{20}.	B.p., ° C.	M.p., ° C.	P_D^{20} × 10^3.	D_D.
Benzene	F	6	6	78·1	0·8790	1·5011	80·11	—	2·999	1·990
Toluene	F	7	8	92·1	0·8671	1·4969	110·65	—	2·705	2·152
o-Xylene	F	8	10	106·1	0·8800	1·5053	144·4	—	2·620	2·496
m-Xylene	F	8	10	106·1	0·8642	1·4970	139·2	—	2·469	2·271
p-Xylene	F	8	10	106·1	0·8609	1·4958	138·4	—	2·456	2·269
Ethylbenzene	F	8	10	106·1	0·8668	1·4959	136·25	—	2·803	2·572
n-Propylbenzene	F	9	12	120·2	0·8615	1·4917	159·2	—	2·446	2·567
*iso*Propylbenzene	F	9	12	120·2	0·8619	1·4910	152·4	—	2·469	2·591
1 : 2 : 4-Trimethylbenzene	F	9	12	120·2	0·8761	1·5050	169·2	—	2·405	2·457
1 : 3 : 5-Trimethylbenzene	F	9	12	120·2	0·8650	1·4989	164·6	—	2·272	2·362
o-Ethyltoluene	F	9	12	120·2	0·8825	1·5042	165·2	—	2·524	2·561
m-Ethyltoluene	F	9	12	120·2	0·8655	1·4965	161·45	—	2·412	2·510
p-Ethyltoluene	F	9	12	120·2	0·8625	1·4947	161·9	—	2·370	2·478
n-Butylbenzene	F	10	14	134·2	0·8606	1·4894	182·8	—	2·348	2·758
tert.-Butylbenzene	F	10	14	134·2	0·8664	1·4927	169·1	—	2·405	2·799
1-Methyl-4-*iso*propylbenzene	F	10	14	134·2	0·8582	1·4904	177·1	—	2·290	2·696
7-Phenyltridecane	F	19	32	260·5	0·8541	1·4810	128·0*	—	1·909	4·413
9-Phenylheptadecane	F	23	40	316·5	0·8491	1·4765	—	—	1·769	5·015
9- 2-Phenylethylheptadecane	F	25	44	344·6	0·8558	1·4806	189·0*	−26·7	1·814	5·538
7-Phenyleicosane	F	26	46	358·6	0·8535	1·4794	196·0*	16·4	1·796	5·727
11-Phenyleneicosane	F	27	48	372·7	0·8531	1·4788	204·0*	20·8	1·776	5·891
1 : 1-Diphenylheptane	F	19	24	252·4	0·9497	1·5394	137·5*	—	2·657	5·124
1-Phenyl-3-(2-phenylethyl)-hendecane	F	25	36	336·6	0·9211	1·5192	197·0*	−60	2·323	6·254
1 : 1-Diphenyltetradecane	F	26	38	350·6	0·9186	1·5202	207·0*	17·9	2·293	6·443
1 : 5-Diphenyl-3-(2-phenylethyl)pentane	F	25	28	328·5	1·0087	1·5725	209·5*	−31·7	3·014	6·944
1-Pentene	F	5	10	70·1	0·6400	1·3714	29·90	—	1·391	1·249
2-Methyl-1-butene	F	5	10	70·1	0·6490	1·3770	30·9	—	1·391	1·227
2-Pentene	F	5	10	70·1	0·6491	1·3799	36·1	—	1·382	1·216
2-Methyl-2-butene	F	5	10	70·1	0·6606	1·3872	38·5	—	1·369	1·178
Di-*iso*butylene	F	8	16	112·2	0·7292	1·4100	—	—	1·449	1·779
1-Octene	F	8	16	112·2	0·7175	1·4089	121·25	—	1·449	1·809
2-Octene	F	8	16	112·2	0·7240	1·4138	125·1	—	1·423	1·755
3 : 4 : 4 : 5-Tetramethyl-2-hexene	F	10	20	140·3	0·7738	1·4342	155·4	—	1·471	2·092
3 : 5 : 5-Trimethyl-2-heptene	F	10	20	140·3	0·7850	1·4367	160·3	—	1·470	2·057
7-*n*-Hexyl-6-tridecene	F	19	38	267·5	0·7960	1·4491	—	—	1·467	3·825
5-*n*-Butyl-4-hexadecene 5-*n*-Butyl-5-hexadecene	F	20	40	280·5	0·7995	1·4510	—	Gl.	1·459	3·966
9-*n*-Octyl-8-heptadecene	F	25	50	350·6	0·8084	1·4554	181·0*	Gl.	1·466	4·911
2-Methyl-1 : 3-butadiene	F	5	8	68·1	0·6804	1·4214	34·0	—	2·080	1·648
1 : 3-Pentadiene	F	5	8	68·1	0·6803	1·4309	42·5	—	2·080	1·637
2-Methyl-1 : 3-pentadiene	F	6	10	82·1	0·7215	1·4462	75·7 76·0	—	2·037	1·802
*cyclo*Pentene	F	5	8	68·1	0·7718	1·4224	44·2	—	1·525	1·064
*cyclo*Hexene	F	6	10	82·1	0·8105	1·4463	82·9	—	1·462	1·151
4-Methyl-1-*cyclo*hexene	F	7	12	96·1	0·8001	1·4417	103·1	—	1·495	1·401
*cyclo*Pentadiene	F	5	6	66·1	0·8035	1·4440	—	—	2·020	1·294
1 : 5-Di*cyclo*hexyl-3-(2-*cyclo*hexylethyl)-2-pentene	F	25	44	344·6	0·9117	1·5001	197·0*	−29·0	1·538	4·345
1 : 7-Di*cyclo*pentyl-4-(3-*cyclo*pentylpropyl)-3-heptene	F	25	44	344·6	0·8999	1·4917	195·5*	−62·3	1·542	4·441
Phenylethylene	F	8	8	104·1	0·9055	1·5464	—	—	3·350	2·780
1 : 1-Diphenyl-1-heptene	F	19	22	250·4	0·9636	1·5565	—	—	3·050	5·676
1 : 1-Diphenyl-1-tetradecene	F	26	36	348·6	0·9267	1·5363	205·0*	14·0	2·583	7·067
1 : 5-Diphenyl-3-(2-phenylethyl)2-pentene	F	25	26	326·5	1·0159	1·5816	210·5*	−31·7	3·109	7·019
Indene	F	9	8	116·2	0·9966	1·5679	182·8	—	3·172	2·626
Hydrindene	F	9	10	118·2	0·9640	1·5378	177·95	—	2·687	2·393
Tetralin	F	10	12	132·2	0·9696	1·5431	206·5	—	2·599	2·564

(or groups) by which the molecular type, represented by such a line differs from the alkane with the same number of C-atoms. In the case of unsaturated hydrocarbons it is positive and large; in the case of naphthenes it is negative and obviously small. It is interesting to note that the distances

between lines *a* and *d* and between lines *d* and *e* are equal, which means that the contribution of a phenyl-group is the same, whether or not such a group was already present. Line *g* may not be regarded as definite, as the only two points which determine it correspond to substances containing a double-conjugated system (both phenyl groups and the double bond are attached to the same C-atom). In reality, it is possible to separate in Fig. 1 the naphthenes with five-membered rings from those containing six-

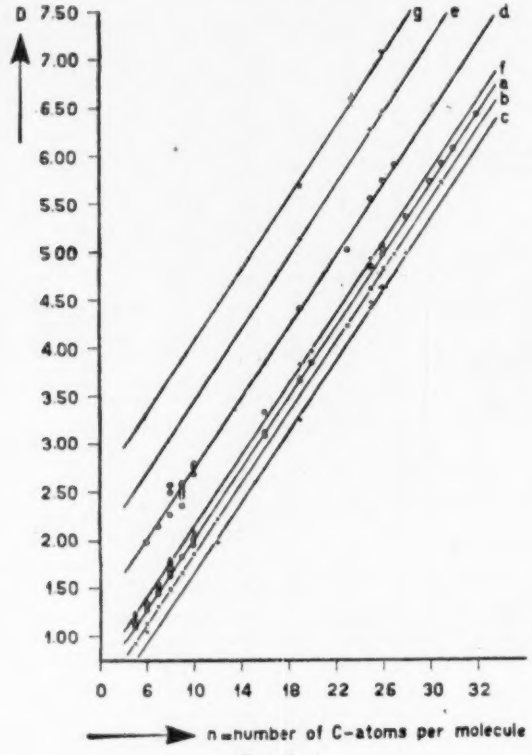

FIG. 1.

CONSTANT D OF DIFFERENT TYPES OF HYDROCARBONS AS A FUNCTION OF THE NUMBER OF C-ATOMS.

(*a*) Alkanes. (*b*) Monocyclic naphthenes. (*c*) Dicyclic naphthenes. (*d*) Phenylalkanes. (*e*) Diphenylalkanes. (*f*) Alkenes. (*g*) Diphenylalkenes.

membered rings, and, in fact, a method which enables one to compute the ratio of these two types of saturated rings in mineral-oil fractions under certain conditions was based on this fact by the authors. In this paper, however, we will not use this property of constant *D*, as it has been extensively discussed in reference 2.

Fig. 1 shows clearly that in many cases the additivity of *D*, combined with the precision with which Eq. (5) holds, may be used if one is interested in the constitution of the average molecule in a mixture. Only if one

wishes to know the mean number of ramifications, constant D cannot be relied upon as, as was already mentioned, the contributions of ramifications depend on their position. It appears, however, that the Verdet-constant V possesses certain properties which could make its measurement an excellent means of determining the mean number of ramifications in mixtures of saturated hydrocarbons with a low number of C-atoms, by means of a graphical method.

This method, which was also developed by K. van Nes and H. Kramers of the Koninklijke/Shell Laboratories at Amsterdam, is illustrated by Fig. 2. In this graph the Verdet-constant V of a great number of alkanes, mainly with methyl side-chains, is plotted against the relative number of

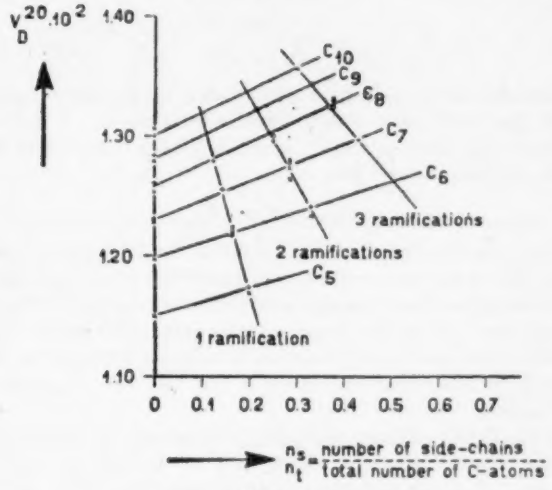

FIG. 2.

VERDET-CONSTANT OF ALKANES WITH DIFFERENT NUMBER OF RAMIFICATIONS AS A FUNCTION OF THE RELATIVE NUMBER OF SIDE-CHAINS.

× Foehr and Fenske's measurements.
+ The authors' measurements.
○ Results of recent, as yet unpublished, measurements.

side-chains per molecule, *i.e.*, the number of ramifications divided by the total number of C-atoms. In the region of low molecular weight, the points corresponding to molecules with one, two, or three ramifications lie on straight lines. A number of lines of constant molecular weight M has also been drawn.

If one takes into account what has been said about the additivity of V in a mixture of saturated hydrocarbons, it is seen that by means of Fig. 2 the mean number of ramifications per molecule in a mixture of alkanes can be determined if the molecular weight, which should not be too high, and the Verdet-constant of the mixture have been measured. It seems that the accuracy of this method is greater than that of the method based on the measurement of the specific parachor. The graphical method described above can be extended to all saturated hydrocarbons, and therefore

appears to be of some interest in the determination of the degree of branching of the average molecule in saturated fractions of the gasoline range. The authors will publish their general results as soon as measurements on a new series of naphthenic hydrocarbons have been made.

Dispersion of the Magneto-optical Rotation.

As mentioned above, measurements of the magneto-optical rotation, carried out at one wavelength λ, may be compared only when the frequency $\omega = 2\pi c/\lambda$ is sufficiently removed from the region where absorption occurs. This follows from the different theories of the Faraday-effect, all of which give formulæ for the constant D of the type :—

$$D = \sum_k \frac{\omega^2 A_k}{\omega^2_k - \omega^2} + \frac{\omega^2 B_k}{(\omega^2_k - \omega^2)^2} + \frac{C_k}{(\omega^2_k - \omega^2)^2 T} \quad . \quad . \quad (6)$$

in which ω_k denotes the kth eigen frequency and A_k, B_k, and C_k are constants, depending on the oscillator strength of this frequency. If ω is sufficiently small compared with the ω_k, and C_k is small, which is certainly the case for hydrocarbons, (6) may be written

$$D = \text{const. } \omega^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

If ω is chosen in such a way that Eq. (7) holds for all types of hydrocarbons investigated, the computed values of D may be compared directly, and even if the measurementswere made at different wavelengths, Eq. (7) enables one to reduce them all to the same wavelength. If, however, part of the investigated substances show absorption at near-by frequencies, Eq. (7) will not hold for them, and their constants D may not be compared with those of other substances.

For this reason the authors thought it necessary to determine the dispersion of the magneto-optical rotation of a number of hydrocarbons of different types. A spectrographic method was developed, enabling them to cover the region from 800 to 350 mμ. The results are shown in Fig. 3, in which the constant D of different substances is plotted against ω^2. In this graph the results of a number of Foehr and Fenske's visual measurements at different wavelengths are also represented. It is seen that, if one uses a sodium arc as light source, the curved part of the dispersion curve is not reached for any of these substances. The picture is the same for all other hydrocarbons mentioned in the Tables I, II, and III. This means that Eq. (7) holds, and that failure of additivity of the constant D cannot be caused by near absorptions.

It may be seen that the determination of the dispersion of the Faraday-effect cannot be regarded as a method which yields much interesting information about the structure of the average molecule in a mixture. In the region of long wavelengths, where D is a linear function of ω^2, such measurements are superfluous, whereas in the range of shorter wavelengths different dispersion curves may even intersect, and all additive properties are wholly lost. One can only say that if constant D is abnormally large in the blue and violet regions of the spectrum, the investigated substance must contain a high number of double bonds. As this number can be better determined by other methods, and as the Verdet-

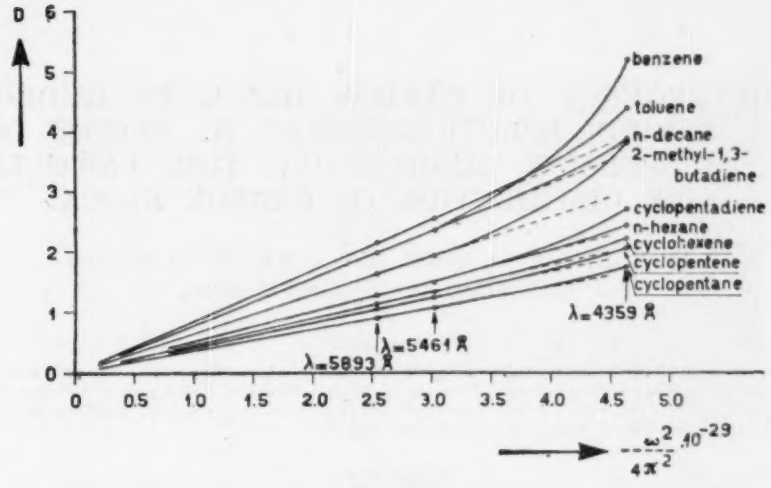

FIG. 3.

DISPERSION OF THE CONSTANT D OF DIFFERENT TYPES OF HYDROCARBONS.

constant will, therefore, mostly be measured on mixtures which have been saturated beforehand, the linearity of the dispersion curve will always hold, and need not be determined anew for every substance.

Delft, *January* 1950.

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DETERGENCY OF CARBON BLACK IN HYDROCARBON SOLUTIONS. PART II. EFFECT OF DISPERSION MEDIUM ON THE PARTICLE SIZE DISTRIBUTION OF CARBON BLACK.

By F. H. Garner, O.B.E. (Fellow),* C. W. Nutt,* and M. F. Mohtadi * (Student Member).

Summary.

An electron-micrograph study of the particle-size distribution of carbon black dispersed in toluene solutions of various additives has shown a correlation between the particle size and the dispersive power of the medium as measured by a standard settling-rate test.

Introduction.

As part of a research programme concerned with the study of " detergency in lubricating oils " an investigation has been made of the influence of various additives on the particle size of carbon black dispersed in toluene solutions of the compounds under standard conditions.

Test Procedure and Results.

The carbon black employed (micronex) was purified as described in the previous paper † of this series. 0·5 G of the carbon black was then dispersed in 25 ml of the toluene solution by application of ultrasonic waves from a magneto-striction oscillator for a period of 2½ min. The solutions tested included :—

(*a*) 1·0 per cent dibromolinoleic acid ‡ in toluene.
(*b*) 1·0 per cent naphthenic acid in toluene.
(*c*) 0·47 per cent calcium naphthenate in toluene.
(*d*) 1·0 per cent " P. 64 " (commercial additive).
(*e*) pure redistilled toluene.

The particle-size distributions of the dispersions were examined by electron-microscopic observation. For this a small portion of the dispersion was diluted (ten-fold or fifty-fold), and a droplet of this dilute dispersion was placed on the collodion film of the electron-microscope object mount. After allowing approximately 1 hr for the complete evaporation of the toluene, the mount was inserted in the microscope and observations made. The purpose of the dilution of the dispersion was two-fold. First, the concentrated dispersion was too dense and black for direct observation; and secondly, it was necessary in order to prevent the aggregation of the particles during the drying of the microscopic slide.

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† *J. Inst. Petrol.*, 1949, **35**, 141.
‡ Prepared by bromination of pure linoleic acid at 0° C.

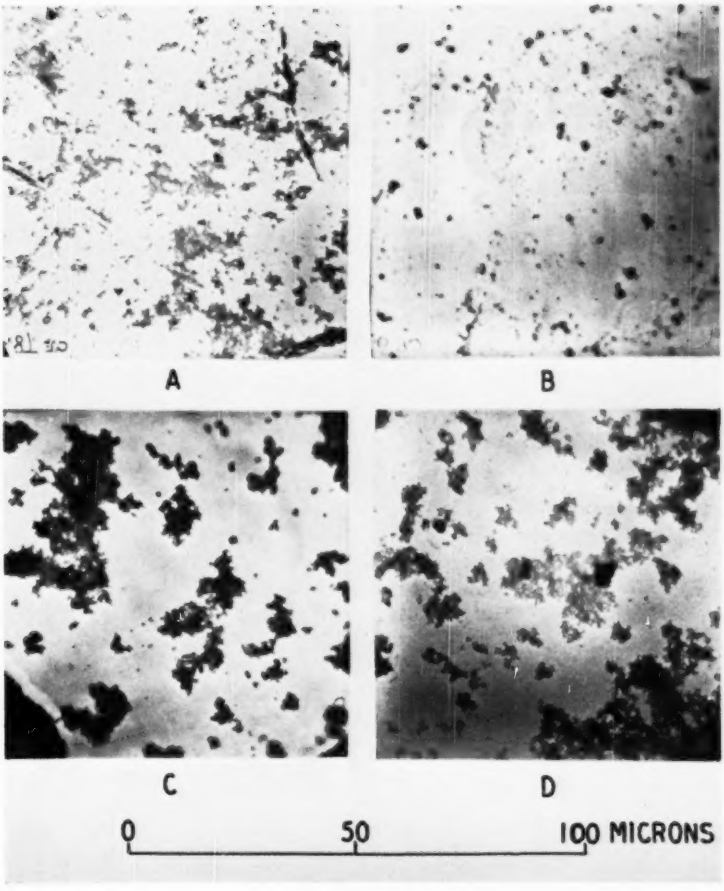

FIG. 1.

ELECTRON MICROGRAPHS OF DISPERSIONS OF CARBON BLACK IN SOLUTIONS OF VARIOUS DISPERSIVE AGENTS IN TOLUENE.

A. 0·5 per cent P.64 dispersion, ten-fold dilution.
B. 0·5 per cent P.64 dispersion, fifty-fold dilution.
C. 1·0 per cent dibromolinoleic acid, ten-fold dilution.
D. 1·0 per cent dibromolinoleic acid, fifty-fold dilution.

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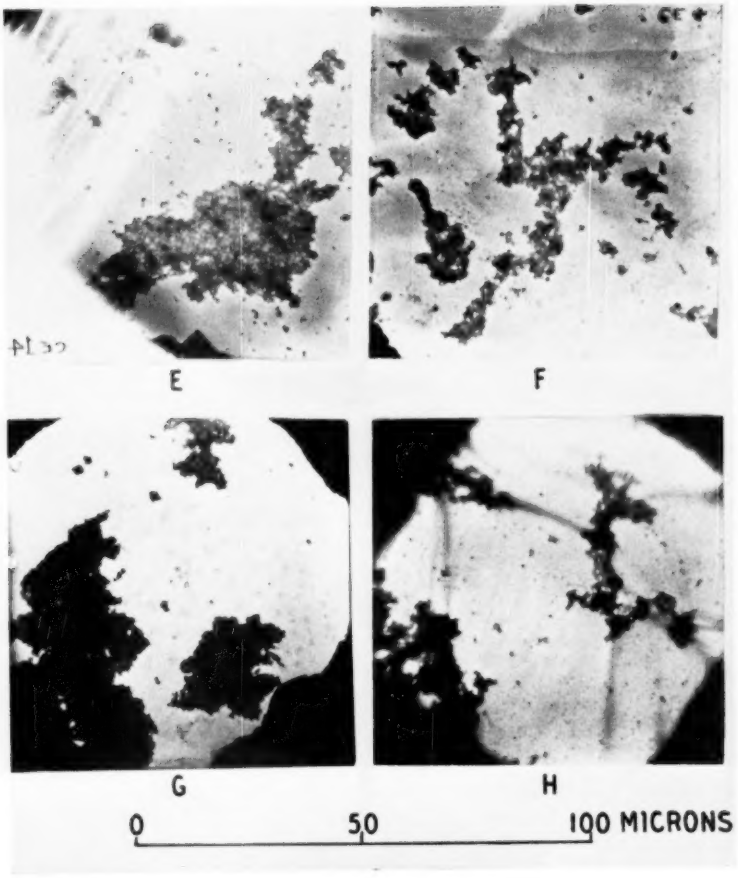


FIG. 1—*continued.*

E. Pure toluene suspension, ten-fold dilution.
F. Pure toluene suspension, fifty-fold dilution.
G. 1·0 per cent naphthenic acid, ten-fold dilution.
H. 0·47 per cent calcium naphthenate, ten-fold dilution.

Typical micrographs for the dispersions examined are shown in Fig. 1. Comparison of (*a*) and (*b*) will show that in the ten-fold diluted dispersions some re-aggregation had occurred, most likely during the drying. This, however, does not invalidate general conclusions which may be drawn from a comparison of the ten-fold diluted samples of the five different suspensions. It will be observed that P. 64 oil is the most effective additive for suspending carbon black in toluene, and is followed by dibromolinoleic acid, calcium naphthenate, and naphthenic acid in order of decreasing dispersive power.

The dispersion properties of the solutions were also examined by means of the sedimentation-rate test described in the earlier paper. All the

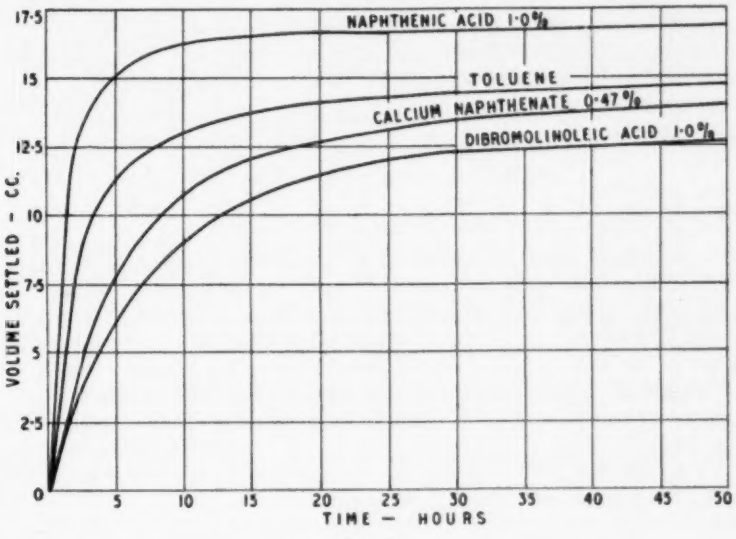


FIG. 2.

dispersions were kept in an air thermostat chamber at 20° C, and as the sedimentation proceeded a sharp interface appeared separating the opaque dispersion from the clear solution on top of it. The volume of the clear solution was recorded as a function of time during a period of 48 hr, and in Fig. 2 these results are plotted, giving the sedimentation curve of each suspension.

The steep slope of the settling curve for the dispersion of micronex in naphthenic acid solution indicates that this dispersion has settled very rapidly, and it is followed by pure toluene sample, calcium naphthenate, and dibromolinoleic acid in order of decreasing rates. In the P. 64 dispersion no sedimentation occurred during one week. These results may readily be correlated with the electron-microscopic observations: the sedimentation rate is an inverse function of the average size of the particles in the dispersion.

It may be thus concluded that the mode of action of the dispersing agents depends on their ability to break down during the exposure to ultrasonic

vibrations, the large carbon aggregates initially present in the micronex. The most effective agents are those which can break down these aggregates most completely.

ACKNOWLEDGMENT.

The authors wish to express their appreciation to Professor J. Sayers and Messrs. Newton and Gianola of the Electron Physics Department of the University of Birmingham for their assistance and co-operation in making the electron-microscopic examinations and providing the micrographs.

LOAD CAPACITY RATING OF LUBRICANTS.

By V. H. Brix.

Summary.

It has always been difficult to rate lubricants in terms of their ability to lubricate. This property is usually expressed as the load capacity, film strength, etc., as determined on some arbitrary test machine. Such results do not always reproduce properly or correlate with service conditions.

Some success, however, has been achieved in recent years with the development of the I.A.E. (now the M.I.R.A.) 3¼-in oil-testing machine. This method possesses, nevertheless, certain drawbacks which limit its more widespread use. For instance, it is necessary to use accurately fabricated and ground test gears.

A machine is described which employs simple test-pieces which can be re-used indefinitely, and which is easy and rapid in operation. The results have a similar trend to those obtained on the I.A.E.-type gear machine, and have shown useful correlation with service conditions.

Oil-testing Machines.

When recommending lubricants for newly designed machinery and motive-power units, it is not easy to judge precisely the qualities most desirable and the relative importance of each quality, because an individual machine or engine responds in its own particular way to various lubricating oils. Diesel engines, for instance, require oils of good quality in respect of ring-gumming and sludge formation, steam-turbines demand high demulsibility, railway locomotives require compounded oils to move heavy trains from rest, and so on.

Within the last decade or so, the automobile and aircraft industries have demanded, above all, lubricants with great chemical stability and resistance to oxidation at high and at low temperatures, low volatility, and high viscosity index. This demand has been met by solvent-refined oils which have qualities formerly only possessed by the paraffinic oils of the eastern U.S.

This improvement in the standard of oils has allowed engine builders to obtain higher b.m.e.p's and to produce hotter, more highly stressed, and more efficient power units than formerly. The same oils have, therefore, been called upon to endure the greater severity of loading conditions especially manifest in components such as gears and cams. Oils are now critical to sliding conditions between such members, and their essential lubricating value is the predominant property called into play. Solvent-refined mineral oils, without additives, are often found deficient in this property, with the result that "scuffing" occurs, a form of welding and surface damage which produces rapid deterioration of moving parts.

Unfortunately, the ability of an oil to lubricate to prevent "scuffing" is most difficult to measure. Whereas chemical stability can to a large extent be covered by precise specifications, the most intrinsic property of oils, their ability to lubricate, still remains undefined and there is not even a proper name for it. Such things as corrosion, gumming, etc., are

well understood, in principle if not in detail, but no general mechanism has been revealed which can explain why one liquid remains trapped between moving surfaces, whilst another fluid with similar physical properties is squeezed out and allows them to scuff or to seize.

" Lubricating value," " Film strength," " Oiliness," etc., all synonymous terms, must therefore be assessed directly by squeezing the lubricant between loaded surfaces in relative motion and determining how much of this treatment each lubricant can stand without the metals being damaged.

Many testing machines have been evolved to rate lubricants in this manner, notably the types in which a flat metal surface is pressed on to the periphery of a rotating disc. Quite considerable instability seems to be the feature of such tests, which embody a condition never occurring in practice, namely pure sliding motion with line or point contact. In many cases, too, attempts are made to rate oils in terms of the groove or scar which is worn away under these particularly violent conditions. Oils are therefore rated *after* damage has occurred, the assumption being that oil A, for instance, is better than oil B because more, or less, wear takes place after the surfaces have seized and the film has evidently broken down.

The property which should be measured is the ability of the oil to maintain stable films between surfaces, to allow surfaces to run against each other perfectly safely without any disturbances. The highest load which can be taken whilst running with absolute safety and stability under prescribed conditions is the only true way of assessing the value of lubricants under those conditions. This aspect of testing has been dealt with previously.*

It is not difficult to see why it has frequently been difficult to rate lubricants on such machines in terms of practical service conditions. It is also clear that the promising results to date have been those obtained on a testing machine in which the test surfaces are actual gear-wheels rotating in mesh under various applied loads. In spite of the very great difficulties naturally inherent when such complicated test pieces are employed, the I.A.E. $3\frac{1}{4}$-in oil-testing machine has given results which seem to agree with experience and service. Even here, however, the element of artificiality creeps in, for it is necessary to start the gears under full load at each load setting. The ability of lubricants to form a film under difficult starting conditions may therefore be confused to some extent with the lubricating values at the operative speeds of the tests. This means that the I.A.E. testing machine may place more emphasis on viscosity than may be justified when recommending oils for most applications such as I.C. engines, turbines, compressors, etc., whose output depends on speed. With this type of machine tests on each oil are carried out on at least two pairs of gears, making four tests in all. The results are averaged. Despite the scatter, the test is sufficiently sensitive to discriminate between oils of similar viscosity but of different origin and blend (I.A.E. Report 1946/R/2).

It follows from the above that a feature most desirable in an oil-testing machine is the combination of rolling motion with sliding. In the I.A.E.

* Brix, V. H. " An electrical study of boundary lubrication," *Airc. Engng*, 1947, **19**, 294.

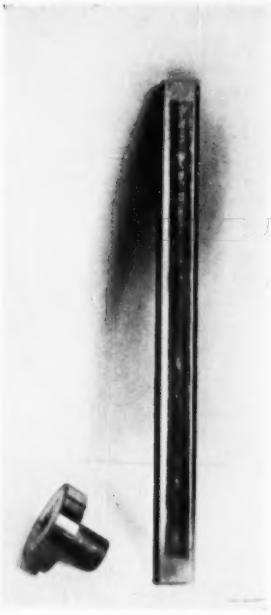


FIG. 2.

TEST PIECES. DISC AND STRAIGHT EDGE, SURFACES SCUFFED.

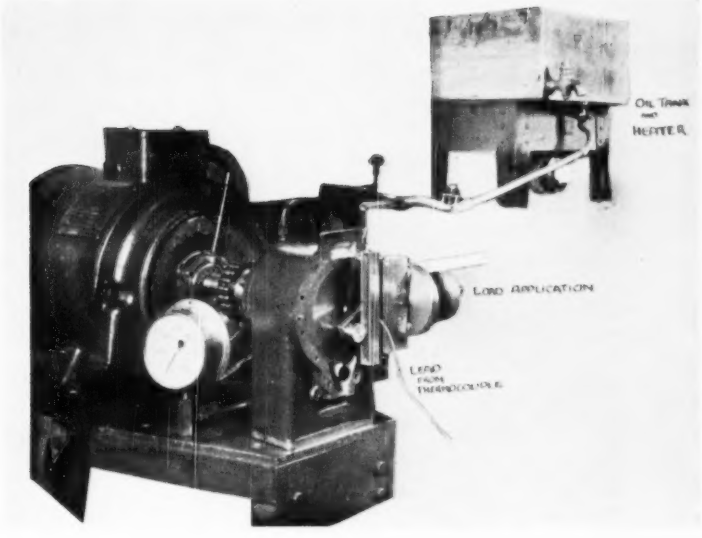


FIG. 6.

ROLL-SLIDE TEST RIG. PRESSURE GAUGE IS FOR THE RIG OIL SYSTEM AND HAS NO CONNEXION WITH THE TESTS.

[*To face p.* 296.

machine this feature is inherent in the gear-tooth action, pure rolling taking place on the pitch line, with the addition of sliding as the line of contact recedes above and below the pitch line. The worst condition occurs where there is maximum sliding, and scuffing therefore takes place to the greatest degree towards the tips and the roots of the engaging teeth.

If the simple type of test machine referred to above, in which a rotating disc rubs against a stationary plate, is modified and a rolling motion imparted to the system, the action between gears and cams is simulated, and the rubbing action distributed over a wide area of both surfaces as the point of contact now moves relatively to both. The actions are therefore not concentrated at one line of contact (or indeed one point of contact as is the case in test machines in which steel balls rub together).

The S.A.E.-type oil-testing machine gained recognition in the U.S. in recent years because it appeared to give answers which agreed with service conditions. It is notable that in this type of machine both rolling and sliding take place, in this case between two rotating discs bearing against each other.

The Roll–Slide Machine described below is of the type in which a plate bears against a disc which rotates and oscillates at the same time. The plate is loaded against the disc by means of a self-aligning feature, allowing the test surfaces to be unaffected by deflections in the machine.

Results Obtained with the Roll–Slide Machine.

There are certain conditions which a test machine for oils should satisfy at the outset. Apart from the ability to reproduce results consistently, several well-known answers should accrue from the test. For instance, castor oil should show considerably better lubricating value, and therefore should give higher load rating than straight mineral oil of equivalent viscosity. Castor oil will indeed stand higher loads than 75 lb, whilst S.A.E. 50 grade mineral oil does not normally exceed 40 lb (corresponding to a " PV " value of $1{\cdot}4 \times 10^6$ on this machine).

There is, too, a generally acknowledged tendency for the load capacity to increase roughly with viscosity of mineral oils. Fig. 1 shows results obtained with a selection of oils of varying grades. The curves are records of temperatures of the " straight-edge " taken at the end of periods of incremental loads, or actually, for better discrimination, the temperature rise from the initial temperature divided by the load in pounds. Temperature is roughly proportional to load until scuffing begins, when there is a rapid rise evident by the sharp upward bend of the curves. The highest load reached *before* scuffing begins is taken as the comparative lubricating value of the oil. At this load and below, the surfaces will run indefinitely without any damage or wear taking place. For instance, the load rating of the H.D. oil is 30 lb, that of the S.A.E. 50 is 40 lb. Higher loads cause scuffing and tearing with, of course, phenomenally high wear. Fig. 2 shows such scuffing.

A further condition of validity of an oil test is that the presence of fatty oils or acids should be evident. This is borne out, for oil D.T.D. 44D is of Pool 14 base stock with the addition of 0·1 per cent stearic acid,

and the improvement due to this is quite manifest. Pool 14 base oil always scuffs as soon as the first load of 10 lb is applied. If 2 per cent rape oil is added, 40 lb load can be obtained without scuffing.

The test machine is sensitive to tricresyl phosphate additive, and to certain other phosphate and chlorinated compounds. Proprietary phosphate treatments of the test surfaces have, also, a very beneficial effect.

Work has been carried out on this machine in parallel with tests on the I.A.E. gear-test machine, and results have shown good agreement with

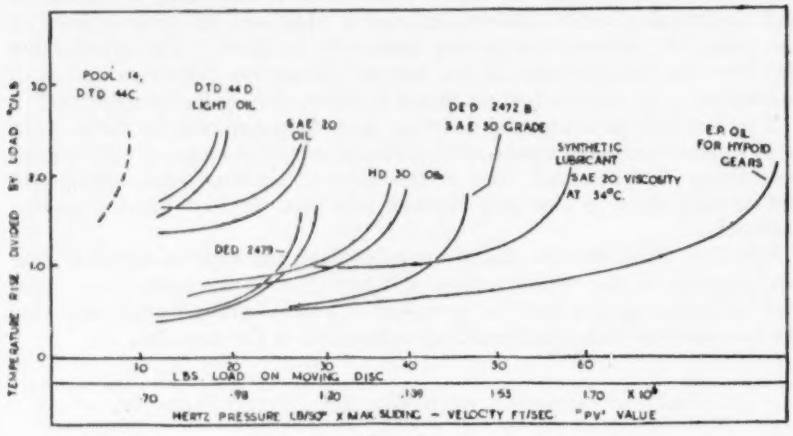


FIG. 1.

RESULTS OF ROLL-SLIDE TESTS ON VARIOUS OILS.

few exceptions. Roughly, the failing load on the Roll-Slide Machine is about one-half of the lever load of the gear test.

The "PV" value range, that is the nominal Hertz pressure between the surfaces in p.s.i. multiplied by the maximum sliding velocity in ft/sec, is from $0{\cdot}7 \times 10^6$ to $19{\cdot}9 \times 10^6$. This is approximately the failure range of automotive gears, but is much too low for high-speed gear-trains such as supercharger drives and gas-turbine propeller-reduction trains. The surface motion is reasonably representative of cam conditions, but the latter have been known to operate satisfactorily up to $PV = 2{\cdot}6 \times 10^6$ with S.A.E. 50 grade straight mineral oil.

DESCRIPTION OF TEST MACHINE.

The test disc is made to revolve uniformly and also to reciprocate in a straight-line motion. This is made possible by the principle of epicyclic motion in which the axes of gear-wheels are made to rotate in addition to the rotation of the wheels themselves.

The principle is illustrated in Fig. 3. The input shaft is driven at *A*, and is integral with the crank carrier *B*, which propels the planet wheel *C* within the stationary annulus *D*. The motion of the planet is reproduced by the crank arm *E*, carrying the test disc on an axis which intersects the pitch circle of the planet wheel.

In Fig. 4 the top sketch represents a planet P rolling within a circle of diameter $2P$. When P is at the topmost position it touches at X. If P rolls a little way round, the point on it which originally was at X and represented by the small rectangle, now moves to a new position which, however, is still on the line XY. It will lie on XY for all positions of the planet within the circle.

The test disc in the machine merely reproduces the motion of the shaded

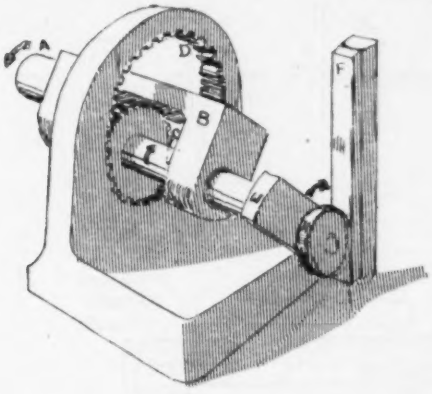


FIG. 3.

PRINCIPLE OF ROLL–SLIDE MECHANISM.

rectangle, and is thus able to describe a straight line path and to rotate as well, one complete revolution per revolution of the input shaft A.

Fig. 5 shows the kinematics of the roll–slide motion. It is a disadvantage that the specific sliding becomes infinitely great at the ends of the stroke, and the test piece is therefore very sensitive to backlash in the direction XY.

Fig. 6 is a general illustration of the rig. Oil is supplied from a heated tank and flows to a nozzle giving a drop feed. The oil is not re-used, but only about ½ pint of oil is required for each test.

DETAILS OF TESTS.

Disc :	
Stroke	5 in.
Diameter	1 in and less as it is re-ground for several tests.
Width	0·25 in.
Disc and straight edge :	
Surface finish	Ground test pieces 12 to 16 microinch "Talysurf."
Material	S.90 steel (not carburized).
Test data :	
Load application	10 min at 0 lb. 10 min at 10 lb. 5 min at 20 lb, 30 lb, etc., up to 60 lb. 5 min at 75 lb.
Rate of oil feed	0·85 pint/hr.
Oil-tank Temp.	70° C (100° S.A.E. 50, 90).
Speed	700 and 800 r.p.m.
Horse-power of Motor	2 h.p.

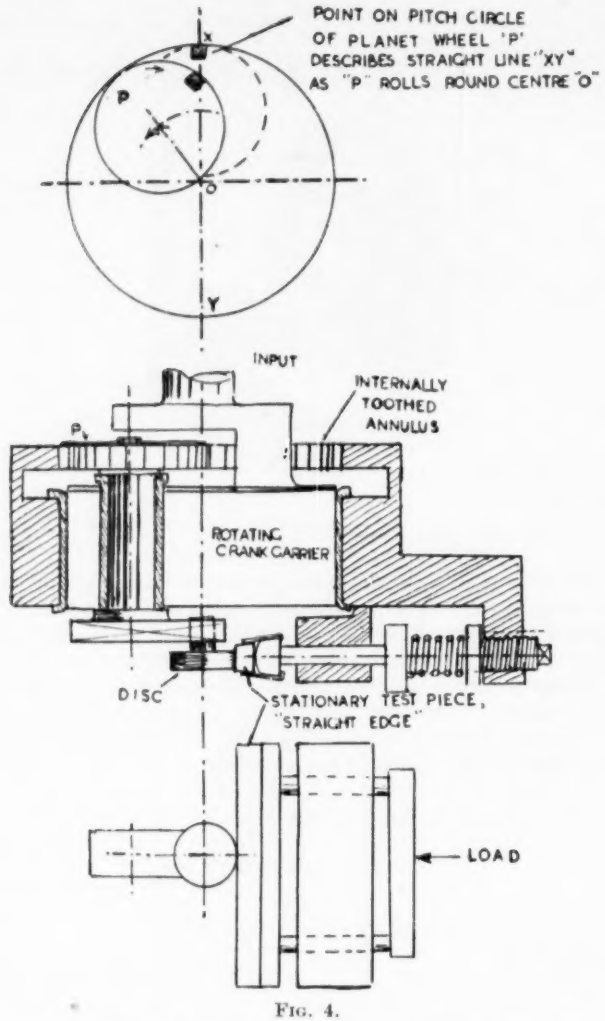


FIG. 4.

DIAGRAMMATIC SKETCHES OF ROLL–SLIDE TEST MACHINE.

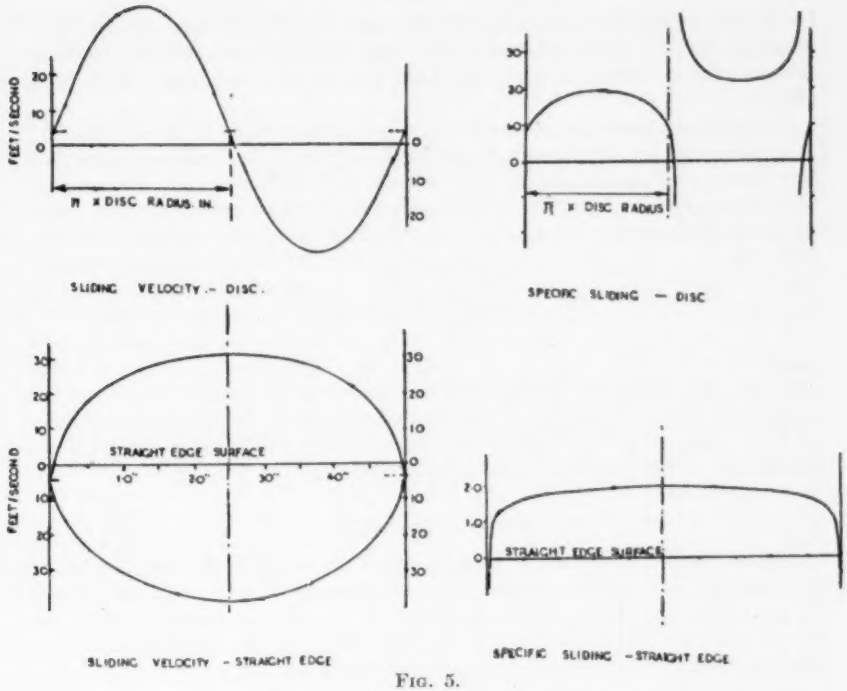


FIG. 5.

KINETICS OF ROLL–SLIDE MOTION.

GENERAL DISCUSSION.

The tests appear to have shown discrimination between oils of similar viscosity grade but of different origin or blend. For instance, Fig. 7

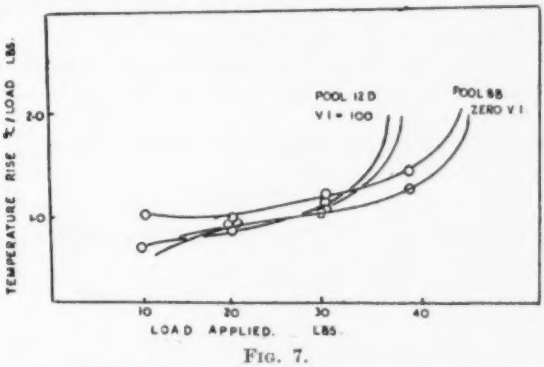


FIG. 7.

COMPARISON BETWEEN TWO S.A.E. 30 GRADE OILS.

shows results obtained on two samples, Pool 12D, a solvent-refined oil with a high viscosity index, and Pool 8B a conventionally refined lubricant.

In the latter case higher load capacity was obtained in spite of the lower viscosity index. It is a widely held view that solvent refining tends to extract certain valuable constituents in natural oils which confer lubricating ability.

A significant instance occurred when a wartime stock of dark "M.160" was employed on development testing of a high-power petrol-engine and the units got through quite well. When the operators took the engines over, they reported troubles in connexion with oil-pump-drive skew gears, which scuffed badly. The trouble was traced to the oil, and on the Roll–Slide Machine this oil consistently stood only 20 lb failure load, whereas the "M.160" took 30 lb. The oil which showed trouble was a blend of H.D.10 and D.T.D. 472B. A change of lubricant cured the trouble.

It is not denied that the I.A.E. gear-oil-testing machine would most probably have been equally successful in discriminating between these oils, but the Roll–Slide Machine is distinctly useful because the tests are easily and rapidly completed. In the case referred to the whole number of four tests could be done in one day. Only small samples of oil are required, and the test pieces are easy to make and to prepare.

Acknowledgments.

The author is indebted to Messrs. Rolls-Royce Ltd. for permission to publish the description of the test machine developed at their Derby laboratories. He also wishes to thank W. J. Davies (Gear Design) for his suggestions, H. S. Royce, H. E. Gresham, and H. Grylls of the Car Division and others for their co-operation and help.

CORRESPONDENCE

"*The Possible Role of Cholesterol and Pyrrole in the Composition of Mineral Oils.*"

To the Editor, *Journal of the Institute of Petroleum.*

SIR,

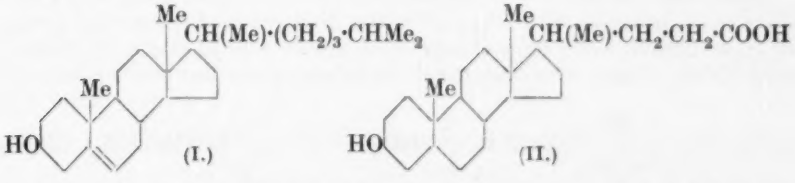
I have ventured to submit a few interesting points *ex-hypothesi* with regard to the origin of aromatic, polycyclic, unsaturated hydrocarbons, and heterocyclic compounds present in mineral oils.

The assumptions have been made, in the first instances, on the biological origin of oil, *i.e.*, the metamorphic changes occurring in strata rich in certain animal phyla—such as the mollusca, etc. Sterols, as many are aware, are closely linked with the early evolutionary process of life, and zoösterols are found in many members of the mollusca family. It is because of such early associations of cholesterol with early forms of life that the following interesting speculations have been made with regard to the composition of mineral oils.

Now assuming cholesterol to be in abundance in such early forms of life, the effect of either heat and pressure or possible oxidation by anærobes may yield a host of derivatives present in petroleum crudes. That petroleum is associated with life, and possibly cholesterol, is suggested by the optical activity of crude oil and occurrence of cholesterol in many crudes. But let us extemporize further—lubricating fractions contain naphthenic acids of the following formulæ: $C_nN_{2n}O_{2-4}$ and $C_nH_{2n-6}O_2$, where n varies between 16 and 24.

The value of n in cholesterol is placed at 27, so the possibility of the afore-mentioned acids being derivatives of cholesterol should not be ruled out. Oxidation of the cholesterol side chain would give acids approaching the above empirical formulæ.

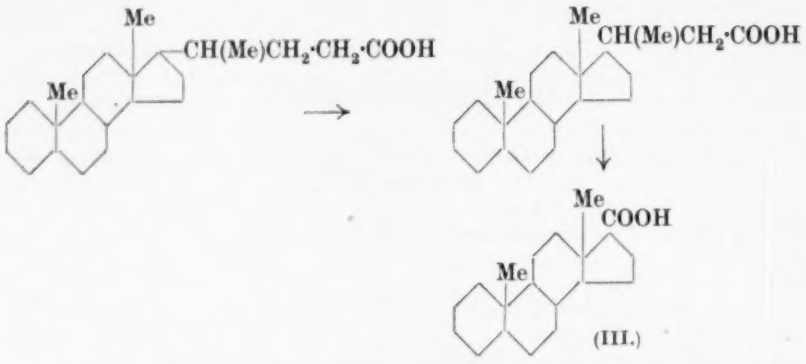
Let us see what derivatives could eventuate from cholesterol (I) under given conditions.



(I.) (II.)

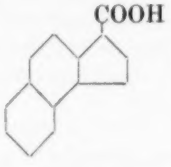
Naphthenic acids could be produced after the reduction of the cholesterol to the dihydro derivative and consequent oxidation of the side chain to yield a C_{24} acid (II).

Progressive oxidation of cholanic could yield acids as illustrated below (III).

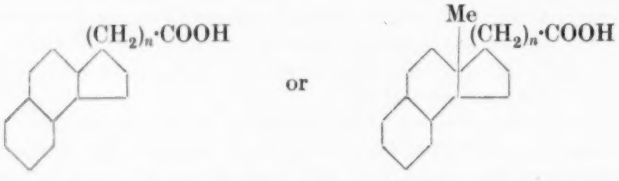


(III.)

At this stage we could state that naphthenic acids with an empirical formula $C_{14}H_{22}O_2$, based on the original formula $C_nH_{2n-6}O_2$, may well correspond to an acid of the below structure :—

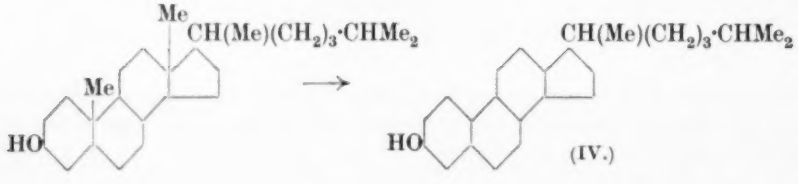


and, of course, we may have the higher homologues



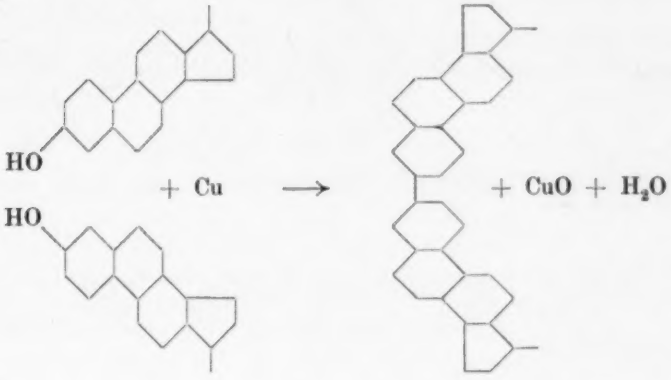
possibly based on the disintegration of the cholesterol fragment. (Naphthenic acid derivatives of the *cyclo*pentane class generally follow empirical formulæ based on $C_nH_{2n-2}O_2$.)

Again thio-oxidation with sulphur (this element being present in many derivatives in crude oil) could lead to the elimination of the methyl groups in such dihydroderivs (*vide* change from abietic acid to retene by Westerberg 1903). Thus, with cholesterol the following reaction may occur :—

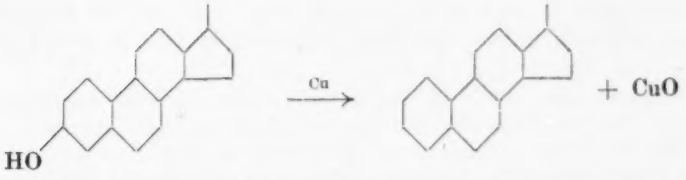


(IV.)

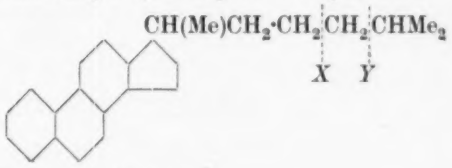
(IV) in the presence of divalent metals may react in either of the following ways :—



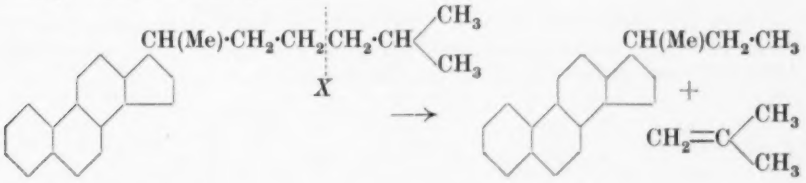
or :—



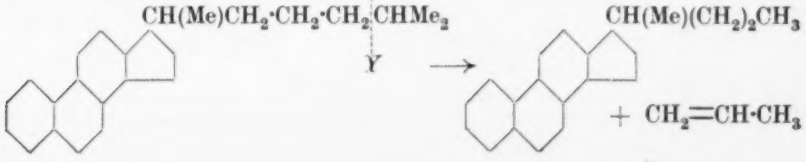
Thermal cracking would invariably occur in metamorphic changes, and this cracking would tend to take place in the side chain of the molecule, yielding, according to circumstances, certain saturated and unsaturated structures; thus cracking may take place at say *X* or *Y*



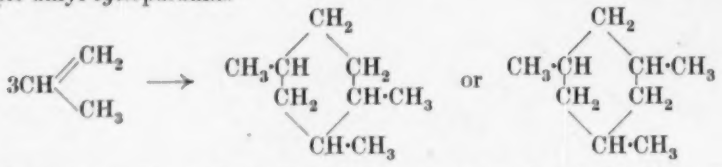
and give the following products :—



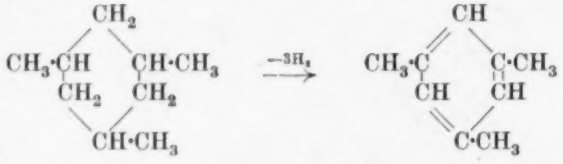
at *Y* we should get



Under heat and pressure polymerization would lead to the synthesis of simple alkyl *cyclo*paraffins

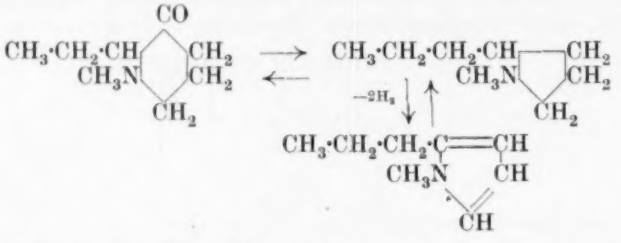


which again would catalytically dehydrogenate to give simple aromatics as seen below :—

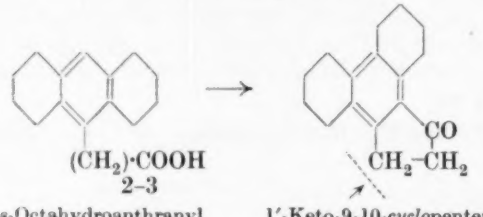


In conclusion, it may be pointed out that cholesterol derivatives are also carcinogenic, a fact coincident with certain grades of lubricating oils.

It is known that traces of heterocyclic bases, such as quinoline, *iso*-quinoline, and pyridine, occur in natural crudes, as these may well result from the intramolecular change of the pyrrole molecule, occurring in the chlorophyll of plankton organisms. This change is obscure, but a process operating in reverse fashion to the Clemmensen reduction of keto piperidine derivatives may afford a possible answer (*ut infra*).



Again HF may be released by the action of water on stannic fluoride under pneumolytic conditions, and anhydrous HF has the effect of cyclizing alkyl polynuclear fatty acids as illustrated below :—

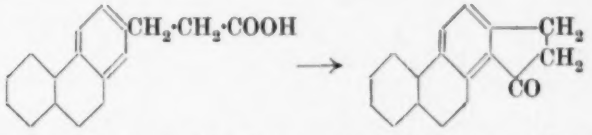


s-Octahydroanthranyl propionic acid.

1′-Keto-9-10-*cyclo*penteno-*s*′-octylhydrophenanthrene.

It will be noted that here we have an α methylene group which may be reactive. This system may be integrated to include tetranuclear and higher polynuclear derivatives.

Further examples may be illustrated below, mixed naphthenes resulting from possible cholesterol fragmentation could yield active carbonyl products as illustrated :—



It must be appreciated that these random remarks are theoretical and have been submitted merely for interest. It is by no means the whole story, but perhaps a small slant on a complex subject.

E. G. CURPHEY

11 *Stanbury Avenue*,
Bebington,
Cheshire.

February 28, 1950.

NOTE.

Sterols occur in abundance in certain sponges and crustaceans. It has been found that sponges contain mixtures of cholesterol and di-unsaturated sterols, and such derivatives have been isolated from the following species : *Haliclona Variabilis*, *H. Viridis*, and *H. Longley*.

Brassicasterol (isomer of stigmasterol) and di-unsaturated derivatives have been found in the *Ostræa Virginica*. *Modiolus Demissus* yields substantial amounts of brassicasterol. The species *Mytilus Edulis* has substantial amounts of cholesterol, brassicasterol, and tri-unsaturated derivatives, such as $\Delta^{5:7:22}$-cholestatriene-3-ol. $\Delta^{5:7}$-di-unsaturated sterols occur in species *Corbicula Leana*. Molluscs and gasteropods contain substantial quantities of 7-dihydrosterols.

E. G. C.

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Oilfield Exploration and Exploitation.

Geology.

915. Coral and other organic reefs in geologic column. W. H. Twenhofel. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 182–202.—This paper was the first of a series read before the American Association of Petroleum Geologists at the St Louis meeting in March 1949.

The writer shows that organic reefs or bioherms are present in every one of the geological systems beginning with the Huronian. After summarizing the various definitions and meanings of the word "reef," and also application of the term "bioherm," the optimum geological definitions of these terms and their characteristics are presented. Their geographical extent and significance from the point of view of porosity and permeability are examined.

It is shown that reefs may have original porosity in three places; the reef itself, the flanking beds, and the over-lying strata. This porosity may be varied by the normal geological process and the work of boring organisms.

It is emphasized that both porosity and permeability may vary very greatly from place to place and from time to time, and these factors cannot be forecast in advance of drilling. E. N. T.

916. Cretaceous and tertiary reef formations and associated sediments in Middle East. F. R. S. Henson. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 215–38.—This paper repeats and expands the substance of a short address given by the author to Section E of the 18th International Geological Congress, which took place in London in 1948, and which was subsequently read before the A.A.P.G. Reef Symposium at St Louis.

The author attempts to summarize provisionally the various observations that have been made on the stratigraphic relationships of some reefs in the Middle East.

Particular interest has been centred on Middle East limestones through the discovery that the rich oil formation at Kirkuk is a reef complex of Tertiary age, while two other fossil reefs of Cretaceous age are highly bituminous.

The author defines the principal types of reef as fringing-reefs, barrier-reefs, shoal-reefs, and bank-reefs.

It is shown that under ideal conditions the various zones of a reef-complex can be differentiated by examination of thin sections and even of well cuttings.

The zone of interdigitation between a reef-complex and the basinward sediments is suggested as being particularly favourable for the formation and accumulation of oil.

It is also shown that the reefs of the Middle East grew in certain sub-littoral zones and on submerged highs in the seas covering the Arabian foreland, in which deposition of a chalk-marl facies predominated.

The paper is illustrated with several cross-sections of reef profiles, as well as photomicrographs of selected samples. E. N. T.

917. Recent reefs. H. S. Ladd. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 203–14.—The ancient reefs of Palæozoic Age have much in common with recent reefs, and the author points out that it is likely that we shall never fully understand ancient reefs until we understand the recent varieties. It is also pointed out that until recently those who had studied the ancient reefs paid little attention to the modern reefs, but there is now a considerable trend away from this attitude.

Existing reefs are complex structures built of calcium carbonate taken from the seawater by shallow-water organisms. Although the conventional classification recognizes fringing reefs, barriers, atolls, and table reefs, the broader classification differentiates the reefs that lie in continental areas from those that rise from the deep ocean.

The factor of most importance in reef control is temperature. This largely explains the development of reefs in the western parts of tropical oceans; reefs are largely absent from the eastern oceanic areas because of the upwelling of cold waters.

Although some reefs are simply coated on various foundations, other reefs are known to be extremely thick, with a depth range far in excess of that of the organisms forming them.

The origin of such thick reefs is still obscure, but it is clear that important changes in land–sea relationships are involved. E. N. T.

918. Theory of transgressive and regressive reef (bioherm) development and origin of oil. T. A. Link. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 263–94.—This is another paper in the A.A.P.G. symposium on reefs which deals with the application of the established geological principles of transgression and regression of coral reefs of bioherm-forming organisms.

Bioherms which develop during a transgression are differentiated from those formed in a retreating sea by the associated sediments. Thus, a transgressive bioherm is associated with marine clastics, while a regressive bioherm is associated essentially with evaporites.

It is suggested that the hydrocarbons within bioherm reservoirs have been obtained from the concn and accumulation of indigenous organisms.

A large number of cross-sections, both actual and theoretical, of North American bioherm deposits is given. E. N. T.

919. International developments. Anon. *Oil Gas J.*, 24.11.49, **48** (29), 53.—The Lakhra well encountered sandstone at 10,770 ft, and this was replaced by shale at 10,858 ft. The sandstone was dry.

In the Burghan field a well designed to explore possible limestone production has passed 5000 ft. G. D. H.

920. California's latest Town-lot field. K. B. Barnes and R. Harwick. *Oil Gas J.*, 6.10.49, **48** (22), 156.—The Placerita field lies 20 miles north of Los Angeles. Production is obtained at depths of 1500–2100 ft, from a 250-ft zone in the Pleistocene and uppermost Pliocene. Initially wells give 1000–1200 b.d., and one gave 2700 b.d. The field is one of a series of pools in the Newhall area on a narrow anticline in the Santa Clara basin. The discovery well was completed in February 1949, and fifty-five producers (fifty flowing) have been completed. The first 150 ft of sand is coarse and conglomeratic; the lower part is finer, with some shale. The oil gravity is 27° on top of the structure, and 18° down dip. Wells cost about $30,000 when ready to produce and with tank battery. They have been completed in seven days. G. D. H.

921. Deeper pay opened at Cuyama. Anon. *Petrol. Engr*, Mar. 1949, **21** (3), B-86.—Anderson 18-30 in the Cuyama Valley flowed 1320 b.d. of 378° oil from a 150-ft pay 500 ft below the Dibblee zone. Total depth of well is 3642 ft. C. A. F.

922. Discovery expands Cuyama Valley field. R. Sneddon. *Petrol. Engr*, June 1949, **21** (6), B-78.—Homan I, 5½ miles southeast of Russell 43-8, had an initial production of 5088 b.d. of 34° oil and 1,500,000 cu. ft. gas. The well is bottomed in the Dibblee zone at 4392 ft, and approx 282 ft of pay were penetrated.

Approx 15,000 b.d. are produced from seventy-three Richfield wells in the Cuyama field, and, excepting six, all produce from the Dibblee sand, probably of Vaqueros age.
C. A. F.

923. Drilling continues in South Cuyama field. Anon. *Petrol. Engr*, Aug. 1949, **21** (9), B-84.—Machader 87-26 had an initial production of 3553 b.d. of 34° oil from a total depth of 4580 ft. The well is 1320 ft north of the Homan discovery.
C. A. F.

924. World's deepest producer 15,250–15,530 ft. K. B. Barnes and R. W. Harwick. *Oil Gas J.*, 13.10.49, **48** (23), 77.—5 Mushrush, 4 miles west of Wasco, Kern County, California, was deepened from 13,130 to 15,866 ft, because the A-2 Lower Miocene sand was nearing depletion. The Eocene was met at 15,000 ft, and groups of perforations were made at intervals between 15,250 and 15,530 ft. On test with a $\frac{5}{16}$-in choke the output was 265 b.d. with 974 M.c.f. of gas. The oil is 43·7° gravity. G. D. H.

925. New gas field. Anon. *Petrol. Engr*, Feb. 1949, **21** (2), B-82.—Pleasant Creek 3-1, 2½ miles northwest of Winters in Yolo County, California, is producing 10 million cu. ft. gas/day from 2820 ft. C. A. F.

926. Colorado pay-off. Anon. *Petrol. Engr*, Jan. 1949, **21** (1), B-68.—Driscoll 1, 25 miles northwest of Cortez, indicated on test a potential of 400 b.d. of 68° distillate and 15–20 million cu. ft. gas from the Paradox Lime, from 5910 to 5935 ft.
C. A. F.

927. Illinois well completed. Anon. *Petrol. Engr*, Sept. 1949, **21** (10), B-106.—1 Burgess in Wayne County had an initial potential of 2807–2863 b.d. from the McClosky Lime at 2980–2987 ft. C. A. F.

928. New Kansas oil pool. Anon. *Petrol. Engr*, Sept. 1949, **21** (10), B-102.—1-B Stumps, 2 miles east of Ames Pool in Barton County, was completed for 3000 b.d. from the Arbuckle, topped at 3283 ft. Production is from open hole at 3285–3299 ft.
C. A. F.

929. Kansas Forest City basin play very active. C. J. Deegan. *Oil Gas J.*, 15.9.49, **48** (19), 167.—The Carter Oil Co. opened a Viola field in Wabaunsee County in May 1949, and now some ten wildcats are located or under way in an area 50 miles from north to south and 10–12 miles wide. 1 Ball, in Lyon County, recovered a little oil from the Lansing–Kansas City at 1604–1619 ft, and a similar find was made by the Carter discovery well. There was a further show at 2022–2026 ft. The Viola was met at 2840 ft, but showed no oil. The Mississippian was met at 2289 ft.

The wildcats and their locations are listed. G. D. H.

930. Wabaunsee County leads. Anon. *Petrol. Engr*, July 1949, **21** (8), B-84.—G. H. Davis 1, in the Davis Ranch pool of Wabaunsee County, Kansas, flowed 2580 b.d. of 29° oil from the Viola Lime from 3199 to 3206 ft. The well is 10 miles east of gas production in the Alta Vista pool in Morris County. C. A. F.

931. Deep pay discovered. Anon. *Petrol. Engr*, Jan. 1949, **21** (1), B-68.—Hammack 1 in the Longwood field of Caddo Parish, Louisiana, flowed on test 2¼ million cu. ft. gas and 159 b.d. of 65° distillate from 58 ft of Cotton Valley sand topped at 8162 ft.

The Longwood field is producing gas, distillate, and oil from the Pettit and Travis Peak from 5600 to 6000 ft. C. A. F.

932. Production depth record shattered. E. Adams. *Petrol. Engr*, Feb. 1949, **21** (2), B-7.—In the U.S. thirteen new fields or pays below 12,000 ft were discovered in 1948, and commercial production was found below 14,000 ft in five separate fields.

Smith-State B-2, in the Weeks Island field, Louisiana, produced 470 b.d. of 33° oil and 475,000 cu. ft. gas/day from 13,826 to 14,159 ft.

Tables give the locations, and formation, mechanical and production data for wells drilled below 12,000 ft during 1948. C. A. F.

933. Offshore discovery. L. S. McCaslin. *Oil Gas J.*, 8.12.49, **48** (31), 38.—A-3 Tiger Pass off the Louisiana coast, Plaquemines Parish, has given 24 b.d. of 64° distillate and 734 M.c.f. of gas on test at 9475–9480 ft. A-2 in the Ship Shoal Block 72 field off Terrebonne Parish, was completed for 3 brl distillate and 1007 M.c.f. gas/day. A Block 58 wildcat off Terrebonne Parish had a good gas test at 11,206–11,208 ft.

Since the war there have been twelve gas-condensate and two dry gas discoveries in Louisiana continental shelf waters. A table lists these wells. Reserves of the order of 2,000,000,000,000 cu. ft. are indicated. G. D. H.

934. New offshore field. Anon. *Petrol. Engr*, May 1949, **21** (5), B-98.—An offshore well drilled 10 miles south of Timbalier Island off Terrebonne parish, Louisiana, flowed on test 456 b.d. of 39·6° oil with G.O.R. of 593 : 1 from approx 9954 ft. C. A. F.

935. Discovers Louisiana gas field. Anon. *Petrol. Engr*, Sept. 1949, **21** (10), B-106.—I R. A. Estes, in Jefferson Parish, made 126 brl of 44° condensate in 18 hr from 11,263–11,267 ft from the Lower Miocene. G.O.R. was 28,571 : 1. C. A. F.

936. Late drilling operations. J. Hancock. *Petrol. Engr*, Sept. 1949, **21** (10), B-13.—Fifty-five wildcats were drilled in Mississippi during the first six months of 1949, of which three were discoveries :

The Bude discovery, 1 J. Pittman, in Franklin County, was drilled to 11,300 ft, and on test flowed 356 b.d. of 43·8° oil from 11,120 to 11,135 ft. G.O.R. was 1580 : 1.

The Armstrong discovery, 1 George Armstrong, in Adams County, was drilled to 6520 ft, and produces 38° oil from the Wilcox at 6467–6471 ft.

The Sand Hill discovery, 1 F. J. Hubbard, in Greene County, pumped 46 b.d. of 25° oil from 7804 to 7812 ft from the Upper Tuscaloosa. The well is in a faulted area.

Three more piercement salt domes have been found in Mississippi, bringing the total to forty-four. No commercial oil or sulphur has been found in tests of these structures.

Wilcox production was found in the Oldenburg field of Franklin County by 1 Lehman Brothers, which initially flowed 246 b.d. of 35·5° oil from 5984 to 5987 ft. The Oldenburg field was discovered in 1947, the discovery well being completed as a pumper in the Lower Tuscaloosa below 10,500 ft. C. A. F.

937. General geology of Mississippi. F. F. Mellen. *Petrol. Engr*, Sept. 1949, **21** (10), B-7.—Approx 400 wells are completed annually in Mississippi. Most of the early wells drilled in the state were shallow and would not now be considered adequate tests. Only a few deep Palæozoic and early Mesozoic tests have been made.

Two north–south sections illustrate the general geology of eastern and western Mississippi. Cambrian to Middle or Upper Pennsylvanian are progressively overlapped northwards by the larger subdivisions of the Mesozoic, which range from the Jurassic Smackover to the Cretaceous. Palæozoic formations outcrop only in the northeast, in Tishomingo County, where there are numerous structures, and many beds are stained or saturated with dead oil.

The eastern Mississippi section shows alternating major structural features, which, from north to south, are : the Nashville Arch, Black Warrior Basin, Central Mississippi Ridge, Mississippi Interior Salt Basin, and the Wiggins Ridge. A buried thrust is suspected between the Warrior Basin and the C. M. Ridge, where Cambro–Ordovician dolomites are in contact with Pennsylvanian shales. The section shows 31,800 ft of sediments.

The western section shows 27,500 ft of sediments and a similar alternation of structural features. Igneous rocks are present in Mesozoic and Palæozoic formations north of the Monroe Platform and are restricted to western Mississippi.

The Cambro–Ordovician consists chiefly of limestones and dolomites, with some shale, sandstone, and chert. Many oil and gas shows have been found.

The Mississippian and Pennsylvanian are chiefly shales and sandstones. Gas was produced from the Mississippian in the Amory Gas Field, Mississippi's first production.

The Jurassic consists of the Eagle Mills salt, which forms the core of the piercement domes in the Salt Basin, and the Marine Smackover, Buckner, and Cotton Valley. The overlying Comanchean is chiefly continental and wedges out northwards.

The Cretaceous consists of continental and marine sands and shales, and the overlying Tertiary is chiefly marine, with sands, silts, shales, and occasional lignites and marls.

Approx 85% of Mississippi's production is from the Cretaceous, with the remainder from the Eocene Wilcox. Large producing structures include the Heidelberg, Tinsley, Baxterville, and Cranfield fields.

Geological conditions indicate that there are large reserves in the state.

C. A. F.

938. San Juan Basin test in limelight. C. J. Deegan. *Oil Gas J.*, 3.11.49, **48** (26), 121.—1 Ingverson in Rio Arriba county of northwest New Mexico has recovered high-gravity oil in two drillstem tests of the Dakota. The tests were at 7654–7802 ft and 7726–7802 ft. The formations were encountered as follows: Picture Cliff 3100–3150 ft, Mesaverde 4731 ft, Mancos 5310 ft, Dakota 7517 ft, Morrison 7750 ft. A good gas show in the Picture Cliff was reported. The test is on the east side of the San Juan basin. G. D. H.

939. Fourth pay zone for Elk City. Anon. *Petrol. Engr*, Jan. 1949, **21** (1), B-68.—J. I. Long 1, in the Elk City field, Oklahoma, found two oil and two condensate zones in thick granite wash. On test, the well flowed 396 b.d. condensate with 2087 million cu. ft. gas from 9549 to 9650 ft. C. A. F.

940. Shell in the Elk City area. Anon. *Petrol. Engr*, Mar. 1949, **21** (3), B-88.—Kelly 1, in Beckham County, Oklahoma, found two oil and two distillate zones. The deepest zone flowed 21 brl/hr from 10,130 to 10,180 ft with a G.O.R. of 1580 : 1.

C. A. F.

941. Opens new pay. Anon. *Petrol. Engr*, Sept. 1949, **21** (10), B-106.—1 Oklahoma State "B" in the Elk City field, Beckham County, Okla., flowed on test 1040 b.d. of 61° distillate from 9546 to 9646 ft, and 1152 b.d. of 57·8° distillate from 9380 to 9472 ft. The well has extended Elk City field 1 mile to the west. C. A. F.

942. New field in South Texas. Anon. *Petrol. Engr*, Feb. 1949, **21** (2), B-92.—Three producing sands in the Frio have been discovered in the new Barosa field at approx 4300, 4500, and 4750 ft. There are five producing wells, and two are being drilled. The field is 3 miles east of the Rincon field in Starr County, and the Barosa sands are correlated with the Rincon C, D, and E sands. C. A. F.

943. Todd deep field, Crockett County, Texas. R. F. Imbt and S. V. McCullum. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 239–62.—The Todd Deep field in Crockett County, Texas, was discovered in April 1940, as a result of surface and sub-surface exploration work. The discovery was completed at a depth of 1542 ft.

Deeper drilling discovered the Ellenburger pool in February 1945. The sub-surface evidence has discovered the presence of a limestone reef on the flank of a sharply folded Ordovician uplift. To date, thirty-four wells have been completed in the Crinoidal zones and sixty-two wells in the Ellenburger.

The Crinoidal limestone is of Strawn age, and consists of an agglomeration of shell fragments which are poorly cemented, of excellent porosity, and which are a source of ideal reservoir conditions. This formation is about 400 ft deep, and is a product of reef deposition.

The Ellenburger formation is composed of white and brown dolomite, with zones of chert and various limestone members. It has a total thickness of approx 1000 ft.

E. N. T.

944. Wildcat finds oil. D. M. Duff. *Oil Gas J.*, 1.12.49, **48** (30), 52.—1 Tortuguero in southern Vera Cruz found oil sands at 4680 ft, and on test gave 1170 b.d. of light oil.

The well is 10 miles northeast of the old Santa Rosa field, and is bottomed offshore by directional drilling. G. D. H.

945. New Lime field. Anon. *Petrol. Engr*, May 1949, **21** (5), B-90.—Ruby Magness 1, in Madison County north of Houston, on test flowed 95 b.d. of 45° oil and 1,300,000 cu. ft. gas/day from the Edwards lime, topped at 9600 ft. C. A. F.

946. East Texas gets new well. Anon. *Petrol. Engr*, July 1949, **21** (8), B-80.—Delta 1 Little Lillie Hoskins, in the south Tyler Paluxy field, flowed 550 b.d of 27·1° oil from the Paluxy from 7638 to 7658 ft. The Tyler Paluxy field started production in 1948, and further exploitation is planned. C. A. F.

947. Scurry County reef play extension? C. J. Deegan. *Oil Gas J.*, 8. 12.49, **48** (31), 113.—1 Von Roeder, 4 miles west of the nearest Canyon production in Sharon Ridge field, recovered gas and oil-cut mud in drillstem tests covering intervals which spread from just above to well down in the Canyon reef. The Canyon reef was met at 6835 ft.

The water level may be at 6910–6935 ft, which is substantially lower than at Sharon Ridge. G. D. H.

948. West Texas hot spots. C. J. Deegan. *Oil Gas J.*, 10.11.49, **48** (27), 397.—1 Powell, which gave good Ellenburger production, extended the Pegasus field of the Upton–Midland county area 2½ miles southeast of the discovery. 1 America Republics has jumped about 1½ miles southwest of Powell, and has found the Pennsylvanian about 100 ft higher.

1 Dunn, in northwest Mitchell County, has made a good well in a reef which is probably older than the big Canyon reef immediately to the north in Scurry County. G. D. H.

949. Oil field evident. Anon. *Petrol. Engr*, July 1949, **21** (8), B-84.—A well drilled in the Cedarville area of Kaufman County, Texas, found 15 ft of saturated Paluxy at 4967 ft, and on test flowed 230 b.d. The Paluxy is one of the prolific pays in East Texas. C. A. F.

950. Mitchell–Scurry County reef trends. C. J. Deegan. *Oil Gas J.*, 29.9.49, **48** (21), 117.—A well in northwest Mitchell County, Texas, a few miles south of the Sharon Ridge area reef production, in a drillstem test at 7565–7685 ft flowed oil and gas from a reef development. In an hour it gave 42 brl of 42° oil, with 18 brl of drilling mud and salt water. The reef is apparently older than that in Scurry County. G. D. H.

951. Midland black shale basin of West Texas. C. J. Deegan. *Oil Gas J.*, 1.12.49, **48** (30), 113.—1 Peck, 4½ miles west and 1 mile north of the Pegasus discovery well, in a drillstem test at 10,114–10,369 ft flowed gas and oil from the Pennsylvanian. The top of the Pennsylvanian is 80 ft lower than at Pegasus. It is unknown whether there is faulting or steep dip associated with Pegasus. A well 1¾ miles south of the most southerly producer at Pegasus was 80 ft high on the Pennsylvanian, but 80 ft low on the Devonian.

Between Pegasus and Benedum 1 Oswalt had an encouraging oil and gas show in the Fusselman, while 1-A Gulf TXL, 12 miles north and east of Pegasus, recovered gas and oil from the Fusselman at 12,573–12,685 ft. G. D. H.

952. West Texas Pegasus field looks big. C. J. Deegan. *Oil Gas J.*, 6.10.49, **48** (22), 361.—A well 2 miles southeast of the Pegasus field discovery well has found some oil in the Ellenburger. Seismic data and subsurface information indicate a big structure. Production is probably from one or two Permian pays and two to four pre-Permian pays in this field. G. D. H.

953. Solid oil discovered in Utah. Anon. *Petrol. Engr*, Aug. 1949, **21** (9), B-71.—In the Uintah Basin, 1 Ute Tribal, approx 150 miles southeast of Salt Lake City, flowed after acidization 1633 b.d. of 32·6° oil from the Tertiary at 9357–9392 ft. The oil, which flows from the well at 94° F, has a pour point of 90° F.

Of four wildcats previously drilled in the Uintah Basin in the Vernal area, three failed to find oil, but the fourth, 1 Ruth Nelson, recovered green oil and some gas from 7090 ft, but was abandoned as unproductive. C. A. F.

954. Town-lot drilling looms in Wyoming. C. J. Deegan. *Oil Gas J.*, 15.12.49, **48** (32), 123.—1 McDonald, near Glenrock on the south side of the Powder River Basin in Wyoming, seems that it may give over 1000 b.d. from the Muddy at 7202–7226 ft. The well is down dip to the northeast of the Big Muddy field. Trapping may be due to faulting or stratigraphy.

5 miles southwest of the Gurley pool, in Cheyenne county, Nebraska, 1 Cruise has recovered oil from the First Dakota sand at 4650–4660 ft. A test in the Second Dakota at 4663–4683 ft showed 2000 M.c.f. gas/day, while a series of tests in the Third Dakota between 4736 and 4781 ft each indicated several million cu. ft. of gas/day. The Gurley pool has five Dakota oil wells. G. D. H.

955. Powder River basin activity. C. J. Deegan. *Oil Gas J.*, 5.1.50, **48** (35), 99.—Salt Creek, discovered in 1906, had reserves of 400,000,000 brl, and Big Muddy opened in 1916 had 35,000,000–40,000,000 brl. Cole Creek, found in 1938, may have 15,000,000–20,000,000 brl. The three fields seem to be on a trend in the southwestern part of the Powder River basin. The Sussex pool, north of Salt Creek, now appears to have a 1½-mile extension.

Near Big Muddy, between Cole Creek and Salt Creek, 4 Unit indicates a 2½-mile extension by a drillstem test at 7488–7524 ft which recovered 4000 ft of 36·7° oil.

Substantial stratigraphic trap production is being developed on the east side of the Powder River basin. On the southern rim of the basin the Lightning Creek discovery is encouraging. G. D. H.

956. Gas well drilled in Arctic basin. Anon. *Petrol. Engr*, Sept. 1949, **21** (10), B-108.—Pressure and production performance of South Barrow 2, 6 miles south of Pt. Barrow in the U.S. Naval Petroleum Reserve No. 4, Alaska, indicate a considerable gas reserve.

All the five wells drilled in the area have had shows. C. A. F.

957. Recent Canadian oil developments. J. D. Gustafson. *Oil Gas J.*, 5.1.50, **48** (35), 63.—On October 1, 1949, Alberta had 1085 producing wells, and now forty-five development rigs are active. Drilling depths range from about 2000 ft in the Cretaceous sands of western Saskatchewan to 12,000 ft in the Madison of the foothills; Devonian pools range 1800 ft at Norman Walls to 6700 ft at Normandville. In the foothills dips are steep and beds hard; in the central plains lost circulation and blow-out risks are the main difficulties in the Devonian.

Gas occurs in sands in the Belly River group, Viking zone, and Lower Cretaceous, as well as in the Devonian.

γ-Ray and neutron logging are proving valuable in limestones, and diamond coring is giving excellent recovery in fractured limestone. Some emulsion trouble has been met at Leduc, and paraffin deposition is troublesome at Redwater.

At Leduc solution-gas drive is dominant in the D-2 zone, while gas-cap and water drive may play some part in the D-3 zone. The D-3 zone at Redwater is undersaturated, but there is a possibility of edgewater drive. The D-2 of Leduc seems to have 10% effective porosity and 25 mD permeability, while the D-3 has 13% porosity and 300 mD permeability; the D-3 at Redwater is indicated to have 10% porosity and 800 mD permeability. G. D. H.

958. Golden Spike spurs Canadian development. Anon. *Petrol. Engr*, June 1949, **21** (6), B-7.—The Leduc, Woodbend, and Redwater fields have a total estimated reserve of 500 million brl.

Schoepp 1, 22 miles southwest of Edmonton near Golden Spike, drilled to 6082 ft, found 545 ft of producing formation, the thickest pay yet found in Canada.

Since Leduc 1, 225 exploratory wells have been drilled in western Canada, of which approx 1 in 25 has found pay. C. A. F.

959. 200-mile NW jump for Alberta oil production. C. J. Deegan. *Oil Gas J.*, 27.10.49, **48** (25), 117.—1 Normandville, 200 miles northwest of Redwater, has flowed 189 b.d. oil in a 7½-hr test. It is producing from perforations at 6730–6745 ft opposite the Devonian. Good shows were reported over an 85-ft interval. G. D. H.

960. Devonian dolomitized reef, D3 reservoir, Leduc field, Alberta, Canada. Anon. *Bull. Amer. Ass. Petrol. Geol.*, 1950, **34**, 295–312.—The Leduc oilfield in Alberta, Canada, was discovered in 1947, and is now an important oilfield.

The D3 reservoir is the lowest producing zone, and consists of a dolomitized Upper Devonian reef.

This paper discusses the thickness of this reservoir formation, and gives data of the variations in its chemical composition, its geo-electric characteristics, and lithology. It is suggested that minor variations in these factors are due to geologic vicissitudes during its growth and subsequent history.

The methods used to obtain data on the volume and inter-relationship of the various types of void space within the reef are given in detail. E. N. T.

961. Large Ontario gas well. Anon. *Petrol. Engr*, Sept. 1949, **21** (10), B-102.—A well drilled 1½ miles northwest of the Kimball gas field has an estimated flow of 15 million cu. ft. dry gas/day from the Guelph–Niagara. Rock pressure is approx 800 p.s.i. C. A. F.

962. Oil search in Cuba : Gulf begins new exploratory test. Anon. *Oil Gas J.*, 22.9.49, **48** (20), 146.—A well has been spudded 3½ miles offshore in Cardenas Bay. This is 60 km northwest of Motemba, which produces from the Upper Eocene on a monoclinal igneous structure. G. D. H.

963. Colombian strike. Anon. *Oil Gas J.*, 8.12.49, **48** (31), 50.—Texas' Tetuan 1, near Ortega in the Upper Magdalena valley, has given 800 b.d. on test. The total depth is 4579 ft, and the oil gravity is 22–23°. At Velasquez, 150 miles to the north, there are three producers. G. D. H.

964. Socony–Vacuum reports good producer ; other tests watched. Anon. *Oil Gas J.*, 13.10.49, **48** (23), 66.—The Morichi well, several miles from Camiri in the Oficina area, has given on test 1000–1200 b.d. from both formations in a dual completion. The depth is about 7000 ft.

The Santa Cruz well east of Mara has been abandoned at 14,045 ft. Sylvester 5 was recently completed, giving five or six wells in this area rumoured to be capable of good producing rates.

An extension to the Cantagallo field has been made by Cantagallo No. 12, which tested 1200 b.d. on a ½-in choke. Casabe 123 is reported to have discovered a new zone, and to have given 800 b.d. on test. G. D. H.

965. Exploratory activity renewed in Ecuador. Anon. *World Oil*, Feb. 1950, **130** (2), 210.—Preliminary geological and geophysical work has been carried out since early 1949 in new concessions along the Pacific coast of Ecuador. Concession terms call for a five-year exploration period, a four-year development period, and a thirty-year exploitation period. Provisions have been made for granting ten-year extensions to the exploitation phase.

Present production in Ecuador is from fields on the Santa Elena Peninsula, which produce approx 7000 b.d. of light oil from relatively shallow Eocene pays. The new concessions contain three main sedimentary basins, which from north to south are : the Progreso Basin, the Tipijapa–Quininde Basin, and the Borbon Basin. Best possibilities are believed to be in the Tertiary, which has an estimated thickness of over 50,000 ft. Twenty unsuccessful wildcats have been drilled in these basins.

C. A. F.

966. Two deep Cretaceous field wells completed. Anon. *Oil Gas J.*, 17.11.49, **48** (28), 52.—Men 2 in the northeast part of Mara has flowed 10,000 b.d. on test. P 105 a westerly outpost is described as a good well. G. D. H.

967. Two more stepout wells completed in Jose Ruiz. Anon. *Oil Gas J.*, 6.10.49, **48** (22), 159.—The Jose Ruiz field now has five producers and a potential of 2700 b.d. of 28·2–36·2° oil.

At Tucupido, 15 miles north of Ruiz, a new shallow well has been completed for 1200 b.d. in a Chaguaramas sand at 3000 ft. G. D. H.

968. Venezuelan discovery well. Anon. *Petrol. Engr*, Feb. 1949, **21** (2), B-94.—A Phillips well, approx 70 miles west of the Mata Grande Pool in Anzoategui, found several pay sands having a total thickness of 165 ft, in the Colorado section of the Oficina between 7740 and 8500 ft. On test, the top zone flowed 1500 b.d. of 40° oil, and the lower zones : 500, 300, and 500 b.d. of 41–45° oil. C. A. F.

969. French discovery well tests 600 b.d. Anon. *Oil Gas J.*, 3.11.49, **48** (26), 50.—The Soultz-zouz-Forets well in the Pechelbronn field penetrated a highly porous part of the Muschelkalk, and production was obtained at 2840 ft. On open flow it was estimated to be 6000 b.d., but under control the rate was 600 b.d. A nearby well completed in 1948 had a sharp fall in output. G. D. H.

970. Alsatian discovery indicates 560-barrel daily production. Anon. *World Oil*, Feb. 1950, **130** (2), 216.—A well 11 miles north of Hagenau in Alsace gushed 6500 b.d. of light oil from the Muschelkalk, not hitherto found productive in France. The production rate was controlled to 560 b.d. C. A. F.

971. Petroleum deposits in the Italian sub-soil. G. Coppa Zuccari. *Chim. et Ind.*, 1950, **63**, 182–4.—There are strong indications of pet deposits in Italy, especially in the Milan–Cremona and Po areas. Standard Oil Co. (N.J.) and Italian affiliates are proposing further exploratory work, particularly if new legislation, more favourable to concession-holders, is passed. Some details of such proposed legislation are given. V. B.

972. Italy gets first well. Anon. *Petrol. Engr*, July 1949, **21** (8), B-82.—Cortemaggiore 1, 20 km east of Piacenza in the Po Valley, on test flowed 175–200 b.d. of light oil with large quantities of gas from 4900 to 5250 ft.

The structure is believed to be a long east–west fold. C. A. F.

973. State company sets up development programme for Upper Po Valley area. D. M. Duff. *Oil Gas J.*, 1.9.49, **48** (17), 30.—The Cortegmaggiore discovery is to be developed by the $1,775,000 A.G.I.P. company. Two wells have found oil at 5250 ft. A second discovery northeast of Parma is reported. North Italy gas wells have a potential of 14,200,000 cu. ft/day, but pipelines restrict output to 10,600,000 cu. ft/day. Pipelines from Lodi to Turin and Genoa are planned. There are hundreds of gas wells (300–1200 ft) in the Po delta, and these supply gas to Venice. In the Upper Po valley are the gas fields of Caviage, Podenzano, Ripalta, and San Giorgio. Production is mainly from the uppermost Miocene or Mio-Pliocene, and the accumulations have been located after geophysical work. Caviaga has fifteen completions, and three dry holes mark the north, south, and west limits. The productive area is now under 2500 acres. The present yield is 8 million cu. ft/day from 200 ft of pay in a 650-ft zone. Caviaga No. 14 blew out with a flow estimated at 30 million cu. ft/day.

Podenzano was opened in 1931, and had about thirty wells at depths of 2600–4000 ft. The east–west anticline is faulted on the north. It is now nearly exhausted, but still gives 8 b.d. of crude with the gas. San Giorgio, a small dome to the northeast, has fourteen gas and oil wells, but is thought to be of minor importance. Ripalta, 6 miles to the northeast of Caviaga, has one good gas well in the Upper Miocene at 5100 ft.

Cortemaggiore was found in 1948. No. 1 gave gas at 4600 ft ; No. 2 recovered some oil in a drill-stem test. The two wells are reported to give about 595 b.d. The structure is about 12 km by 4 km, and a producing area of 12,500 acres is estimated. It is a narrow east–west fold, possibly with several highs. Near Piacenza seismic work has revealed the several gas structures to run east–west or E.S.E.–W.N.W.

The Emilia oil production of the Apennine foothills is at 500–2000 ft, in the Argille Scagliose of Cretaceous or Eocene age. The oil is filtered, and the output is now only about 200 b.d. G. D. H.

974. Well extends Benedum pay. Anon. *Petrol. Engr*, May 1949, **21** (5), B-94.—A 2½-mile northeast extension of the Fusselman pay in the Benedum field has been indicated by Alford 2, which on test at approx 11,000 ft blew gas estimated at 8 million cu. ft/day. C. A. F.

975. Outpost extends new German field into Dutch territory. Anon. *Oil Gas J.*, 27.10.49, **48** (25), 50.—S-92 on the west plunge of the Ruehlertwist–Ruehlermoor field has extended the field into Dutch territory. On test it gave 285 b.d. G. D. H.

976. German success. Anon. *Oil Gas J.*, 8.12.49, **48** (31), 52.—1 Scheerhorn, 2 miles north of the Georgsdorf field, has given 450 b.d. on test. The Bentheim sand was met at 3670 ft. The oil is in a stratigraphic trap.

Kuhlenberg 2 in the old shallow Kuhlenberg field has found new production at 3940 ft. The oil is in the Wealden above a salt dome.

Ruehlertwist 4, 1 mile west of the discovery, has obtained oil at 2640–2755 ft.
G. D. H.

977. Turkey schedules 10 wells in Ramandag field for 1950. Anon. *Oil Gas J.*, 5.1.50, **48** (35), 68.—In mid-1949 Ramandag had four wells and an indicated output of about 3000 b.d. The oil is asphaltic and 20° A.P.I. Three rigs are now in operation. Production comes from 4250 ft. The structure may be 40 miles long and 7 miles wide, but only 4 sq. miles has been proved. One well was drilled to 7000 ft. The field was discovered in 1948; the first drilling was in 1939, and wells eventually showed the structural crest to be outside the Maymune valley. The first well pumped 30 b.d. from Upper Cretaceous limestone. A second swabbed over 300 b.d. G. D. H.

978. New field near Baku important, Reds claim. Anon. *Oil Gas J.*, 27.10.49, **48** (25), 50.—The first production from Buscovny on the edge of the proved Baku area was obtained during the war. It became important in 1946, and in 1947 several deeper horizons are said to have been opened. It is believed to give 20,000 b.d. now.
G. D. H.

979. Drilling in Iraq. Anon. *Petrol. Engr*, May 1949, **21** (5), B-90.—The Nar-Umar wildcat, northwest of Basrah, has been completed for 2500 b.d. from approx 8360 ft. Drill-stem tests were made on three zones, at 2800 ft, 3400 ft, and 3800 ft.
C. A. F.

980. Lakhra wildcat finds deep sandstone bed. Anon. *Oil Gas J.*, 17.11.49, **48** (28), 55.—The Lakhra wildcat in Sind Province, Pakistan, has encountered sandstones below 10,770 ft, after penetrating 7000 ft of shales. The sandstone is hard and gritty. Pockets of high-pressure gas had previously been encountered. G. D. H.

981. Pakistan well yields 1692 barrels after acidization. Anon. *World Oil*, Feb. 1950, **130** (2), 215.—Chakwal 2, West Punjab, is producing 1692 b.d. after acidization, and an optimum of 2000 b.d. is expected. C. A. F.

982. The southward extension of the Assam oil-belt. A. K. Day and V. H. Boileau. *Indian Min.*, Oct. 1948, **2** (4), 256.—In addition to the producing field at Digboi in Upper Assam and the abandoned Badarpur field in Cachar, there are oil and gas indications between these areas along the northeast–southwest front of the Naga Hills. Small quantities of oil have been recovered from a shallow horizon at Masimpur, 10 miles east of Badarpur, and there are seepages at the foot of the Khasi and Garo Hills, which hills form a diverging branch of the oil-belt to the north of the Bengal–Bay of Bengal depression.

To the south, on the east side of the Bay of Bengal, there is small production, chiefly from hand-dug wells on islands off the Arakan coast. Numerous mud volcanoes, mostly submarine, indicate an extensive oil- and gas-bearing area, but no commercial pools have been discovered in the southward extension of the belt. Oil indications are confined to the eastern part of the belt, where the folds are compressed and broken,

but to the west trap conditions are more favourable as the folds become gentler and are progressively covered by younger beds.

The stratigraphy and structure of Tripura State is briefly discussed. C. A. F.

983. Oil exploration in Assam. J. Coates and H. R. Tainsh. *Indian Min*, Jan. 1949, **3** (1), 12.—A test well drilled at Tiru Hills in Upper Assam failed to find oil, and a resistivity survey showed all sands to be water-bearing. The well was sited on a small dome associated with the Naga thrust on the northwest boundary of the Naga Hills. The rocks exposed at the surface are correlated with the Mio-Pliocene Girujan Clay and Tipam Sandstone.

Before the war a torsion-balance survey was made of the area to define the sub-alluvial position of the Naga thrust, which is not exposed at surface. It was hoped that oil would be found in Tipam and Surma sands in an anticline above the thrust, but the well showed these to be barren in spite of good trap and reservoir conditions.

Operations in this area have been abandoned, and plans are being made to test a small dome in the Barsilla area which is also associated with the Naga thrust, but which is structurally separated from the Tiru Hills dome. C. A. F.

984. New deep pay in Japan's Yabase field looks good. Anon. *Oil Gas J.*, 10.11.49, **48** (27), 193.—A well in a deep pay at 4000 ft in the Yabase field has given 220 b.d. on a ½-in. choke. The second well swabbed and flowed 90 brl of oil and 35 brl of mud in 24 hr. G. D. H.

985. New find in Japan. Anon. *Oil Gas J.*, 1.12.49, **48** (30), 47.—Yabase's 1500 b.d. output is 35% of the Japanese oil production. Production is from Zone VII at 3400 ft, and wells give up to 150 b.d. The deeper Zone VIII at 3800 ft had a well giving 272 b.d. initially, and further wells have shown a greater producing area than was originally expected. Its reserves may be 6,000,000 brl.

Seismic work has revealed a large anticline west of the Yabase field, and this will be tested soon.

Yabase has over 600 wells on a gentle anticline. There are nine producing zones. In the Sasaoka oil is at 300 ft, and in the Katsurane at 600 ft, 800 ft, 1100 ft, and 1200 ft. The Funakawa produces at 1300 ft and 2500 ft, while the Onnagawa gives oil at 3300 ft. Before discovery of Zone VII Yabase was believed to have 40% of Japan's proved oil reserves.

In 1947 Japan's daily output averaged 3500 brl, and in 1948 3070 brl.

A new pool has been opened at Kaji. A wildcat at Toyotomi in northern Hokkaido has given 313,000 cu. ft. of gas daily. Operating methods are out of date. In 1948 thirty-three wildcats gave fourteen producers aggregating 300 b.d. The 1948 oil consumption was 10,949,300 brl, of which 1,116,085 brl was produced internally. G. D. H.

986. Australia searches for oil at home and in Papua. Anon. *Petrol. Engr*, May 1949, **21** (5), B-70.—The Papua–New Guinea area is believed to offer the best oil prospects in the Australian region. Exploration is in progress in Papua, Central Queensland, Northwest Australia, and in one or two smaller areas. Oil production in Australia is confined to shale-oil projects at Glen Davis, west of Sydney, and Lakes Entrance, Victoria.

In Papua oil indications were first discovered in 1911 at Opa, and after several preliminary attempts a well was drilled at Kariava, which was abandoned at 12,000 ft. A second well at Oroi is being drilled, and as a result of intensive geological and geophysical surveys, further tests are planned.

In the Rolleston district of Queensland twenty-five shallow tests have been made. In the Roma district, where natural gas was discovered in 1900, magnetic and gravity surveys are being made of the granite basement. In Northwest Australia there are two extensive sedimentary basins. One is in the Kimberley district at the extreme north of Western Australia and the other is the Northwest Basin, which extends from below Shark Bay to above Exmouth Gulf midway up the coast of Western Australia.

In the Kimberley Basin geological surveys have been made of the Nerrima structure which was tested before the war.

In the Northwest Basin, a geological survey is in progress. No oil indications have been found in the few deep water wells drilled in the area. C. A. F.

Geophysics and Geochemical Prospecting.

987. Geophysical equipment and methods. J. Howard. *Instrum. Prac.*, 1950, **4**, 129–35.—An account of geophysical instruments used in oil prospecting, displayed by the Scientific Instrument Manufacturers' Association at the Fourth Empire Mining and Metallurgical Congress at Oxford. Details of operating principles of a number of instruments are given, with notes on their historical development. Included are the Amerada sub-surface pressure gauge, used for carrying out depletion surveys to calculate the amount of oil in a reservoir which is available at economic pressure; nine different gravimeters; two seismographs; and several recent elec methods of geophysical prospecting, all based on the fact that ore bodies are better conductors than the surrounding strata, which somewhat limits the scope of these methods. It is emphasized that all geophysical methods indicate only underground rock structure and do not actually disclose the presence of oil. A. C.

988. Oilfields of northwest Germany. W. J. Arkell. *Nature*, 1949, **164**, 996.—Description of structure map of 20,000 sq. km of N.W. Germany, based on results of surveys over ten years. The map shows the oil structures at whatever depth they may lie, stripped of all obscuring strata. H. C. E.

989. Geophysical exploration in the Paraguayan Chaco. H. Cox. *Petrol. Engr*, May 1949, **21** (5), B-17.—The occurrence of producing oilfields along the eastern flank of the Andes in Peru, Bolivia, and Argentina has encouraged exploration of the Paraguayan Chaco.

Exploration of the area began in 1945, and geological reconnaissance showed the surface beds to be relatively recent and generally flat-lying. As a result of preliminary geophysical surveys, three test wells have been spudded in western Chaco. C. A. F.

990. Geophysical prospecting for oil in India. P. Evans and J. Coates. *Indian Min.*, Oct. 1948, **11** (4), 219.—Large-scale geophysical surveys have been made in northern India, where Tertiary formations are overlain by extensive tracts of alluvium. Electrical, gravity, magnetic, and seismic methods have been used. An electrical survey of an area near Digboi, Assam, successfully defined the suballuvial outcrop of Tertiary sands and clays near the crest of an anticline. Magnetic anomalies found bear no relation to the trend of the sediments.

Prior to 1937, surveys were concentrated on local problems, but an intensive regional prospecting programme has since been carried out. Preliminary reconnaissance using a network of Holweck gravimeter traverses was made to obtain the general distribution of the gravity anomalies. This was followed by observations with Ising or Thyssen gravimeters and torsion-balance surveys in order to outline areas for subsequent detailed seismic surveys. Seismic work was interrupted by the war, but it has now been resumed, and operations are centred in the Indus Valley. C. A. F.

991. Patent. D. Silverman, assr. to Stanolind Oil and Gas Co., U.S.P. 2,495,781, 31.1.50. A shield of radiation-absorbing substance for well-logging instruments. C. F. S.

Drilling.

992. New logging method. K. B. Barnes. *Oil Gas J.*, 29.12.49, **48** (34), 35.—Contact electrodes with spacings of 1–2 in are being employed in electric logging in Scurry County, Texas. These "micro-logs" supplement other types of logging. Because of the small spacing the influence of the mud cake is relatively high. Opposite permeable beds the resistivities will generally be low, but as the resistivity of the invaded zone is usually greater than that of the mud cake, the resistivity value generally increases with the spacing. Opposite an impervious and conductive bed such as shale all spacings should give approx the same low resistivity; in a hard formation all resis-

tivities should be very high. The boundaries of permeable and non-permeable streaks are closely defined. G. D. H.

993. Electric log analysis in the Rocky Mountains. M. P. Tixier. *Petrol. Engr Ref. Ann.*, 1949, **21** (7), B-34.—A method is described whereby a good approximation of the water saturation and porosity of reservoir rocks in the Rocky Mountain area can be obtained.

The method, which is derived from the fundamental formula for the quantitative study of electric logs, as given by Archie, makes use exclusively of data derived from resistivity and SP logs. It is based on an empirical relationship between water saturations in the uncontaminated formation and in the invaded zone, and on the relationships between SP deflections and mud and connate-water resistivities, as determined from field experiments.

Examples of the application of the method are described. C. A. F.

994. Obtaining and interpreting continuous logs in wells in order to make completions. W. Ziloff., *Rev. Inst. franç. Pétrole*, Nov. 1949, **4** (11), 608–14.—Apparatus is available which is capable of detecting in the drilling mud oil or gas released by the disintegration of the rock during drilling. A knowledge of the hole size and drill-pipe dia, and the rate of pumping and drilling advance, permits the point of origin of such oil and gas to be determined with considerable accuracy. Mobile laboratories have been constructed for mud analysis with a view to detecting oil and gas, and determining their point of origin. Salt-water intrusions can be detected. The mud is continuously sampled, and pump speed and drilling rate are recorded.

The technique is not costly in operation, and indicates zones which may merit side-wall coring. G. D. H.

995. Factors involved in removal of sulphate from drilling muds by barium carbonate. W. E. Bergman, H. B. Fisher, and P. G. Carpenter. *Petrol. Tech.*, July 1949, **1** (7), *A.I.M.M.E. Tech. Pap. No.* 2639, 197–204.—Experimental data are presented on the removal of sulphate by barium carbonate and hydroxide from bentonite suspensions and from bentonitic mud containing caustic and quebracho. Comparable data on aqueous solutions are also presented. The experiments and theoretical discussion emphasize that the removal of sulphate by barium carbonate may not be as effective as is generally believed; indeed, the amount of sulphate remaining in the system at equilibrium may be high. The amount of sulphate remaining in solution at equilibrium was primarily a function of the carbonate concentration, the barium concn and the ionic strength of the system. The presence of interfering substances, which form difficultly soluble complexes or compounds with barium, may complicate the removal of sulphate by barium carbonate.

Successful treatment of a drilling mud for removal of sulphate by barium carbonate requires at least that the barium carbonate be rendered soluble by having a low pH or that the carbonate ion concentration be kept low. The latter condition can be attained by the addition of a soluble calcium or barium salt (*e.g.*, the hydroxides). A high pH favours complete precipitation of carbonate as the calcium of barium salt. Thus the use of barium hydroxide is indicated when the sulphate contamination is not primarily due to anhydrite or when the carbonate concn in the mud is high.

G. D. H.

996. Cleaning of oil wells. B. Bem. *Nafta*, Dec. 1948, **4**, 370–1.—Described an invention of W. Łodzinski which enables the quick washing of the well with hot oil or mud. For cases of persistent stoppages in big wells and in the formation, washing fluid should be left in the well for a few days. The above methods were tried out in Hungary and proved effective. M. S.

997. The cost of drilling production. K. Mischke. *Nafta*, Dec. 1948, **4**, 378–81.—For the sake of planning and estimates we accept a certain ratio x/y of depth drilled to costs incurred. To allow for varying hardness of rocks this ratio derived statistically should be $\frac{1}{4}\ x/y$. Over a period of time labour expenses remain steady and other expenses increase with depth of drilling so $y = c + kx$ and ratio $= \dfrac{c}{c + kx}$. For this

reason cost per metre drilled can be used only for comparison, and for planning cost per year or month is more useful. M. S.

998. Improvement of the mobile type of steam boiler used in the oil fields. L. Slotwinski. *Nafta*, Dec. 1948, **4**, 381–2.—Author points out the disadvantages of the types used due primarily to low water capacity and priming losses. It is also pointed out that types designed for burning crude can be adjusted to burn gas. M. S.

999. Modern well surveying instruments for the determination of deflection. H. Gorka. *Nafta*, Dec. 1948, **4**, 360–5.—Author points out the necessity for determination of deflection and mentions a Russian case where the well was spiral and so missed the oil-bearing formation. Deflection is caused by a horizontal force which is present during drilling.

Measuring devices fall into two categories: (*a*) those necessitating the interruption of drilling and (*b*) those that do not. Also (*a*) simple instruments for measurement of angle and (*b*) more complicated ones giving also azimuth. The instruments use liquid levels, or pendulum or electrical resistance measurements.

German, Russian, and American instruments are described. Recording methods described include film recording, photo-electric cells, and mechanical methods.

M. S.

1000. Diamond drill hole G-M counter. K. Feldman and G. M. Wright. *Canad. J. Res.*, 1949, **27F** (2), 23–7.—A portable instrument is described for making γ-ray surveys of diamond drill holes of not less than 1·25-in dia to depths of 1000 ft. D. F. J.

1001. Patents. J. P. Murphy and H. E. McKinney, assrs to Shell Development Co. U.S.P. 2,493,992, 10.1.50. An electromagnetic fishing tool for use in well installations.

J. T. Hayward. U.S.P. 2,494,092, 10.1.50. An apparatus for logging wells in terms of drilling rates when rotary drilling a well.

J. Frost. U.S.P. 2,494,803, 17.1.50. Describes a multiple passage pipe section for oil well drills or similar equipment.

W. P. Morris. U.S.P. 2,495,073, 17.1.50. A well-drilling tool.

E. B. Williams. U.S.P. 2,495,400, 24.1.50. Drill bit.

H. J. Woolslayer, C. Jenkins, and W. H. Luttgen, assrs to Lee C. Moore Corpn. U.S.P. 2,495,563, 24.1.50. Drilling mast. The method for erecting is described.

C. F. S.

Production.

1002. Production research—present and future. M. M. Muskat. *Petrol. Tech.*, July 1949, **1** (7), 9–16.—Scientific curiosity led to the early studies of the properties and behaviour of petroleum fluids and petroleum-bearing rocks. Bottom-hole pressures were measured and bottom-hole samples were obtained; cores were cut. There is now gross understanding of oil reservoirs and their producing mechanisms. Gas solubility in oil has been studied, together with the visc, surface, and interfacial tensions of the solutions. Data have been obtained on condensate reservoirs. Retrograde accumulation of liquid increases until pressures fall to 1000–2000 p.s.i., after which there is partial vaporization. The latter process is incomplete, and the residue may be 30–60% of the initial stable condensate.

Productive sandstones may have porosities ranging 5–35%, while limestones are commonly in the range 4–30%. Producing sandstone permeabilities are from 5 mD to several thousand millidarcies; limestone may have lower as well as higher permeabilities. Connate water is usually 10–50%. Core analysis is now a routine procedure. Permeabilities are a function of the fluids when the rocks contain clay, and the proportions of the fluids when more than one is present.

The equilibrium saturation represents the lowest saturation of oil or gas at which continuity of the phase first develops, and it can assume a non-vanishing permeability.

Usually two and sometimes three controls are operative in the reservoir, the dominant mechanism being determined by the method of production. Recovery by solution

gas drive may be 15–50%. Gas injection may increase the oil recovery by 50% of that yielded by solution-gas drive.

When the rock is highly variable an initial solution-gas drive by expelling oil from tight parts may prevent its being completely by-passed by channelling of water as could occur in complete water drive. Water drive generally gives recoveries of 40–80%, depending on formation uniformity.

Gravity drainage is often referred to as gas-cap expansion, but the cap expansion is incidental. For effectiveness dips must be high, and the visc low. It is highly rate sensitive. The limiting saturation is fixed by breaking up of the oil mass. Recoveries should range 40–80%. Gas injection prolongs flowing life and maintains oil mobility.

Much research is now devoted to refinement of present techniques and to clarifying currently accepted concepts. It appears that complete static thermodynamic equilibrium does not exist in many oil reservoirs, despite their great age. Non-equilibrium processes may play some part in production. A 1% recovery of present "irrecoverable reserves" would be valuable. G. D. H.

1003. The effect of well spacing and drawdown on recovery from internal gas drive reservoirs. R. G. Loper and J. C. Calhoun. *Petrol. Tech.*, Aug. 1949, **1** (8), *A.I.M.M.E. Tech. Pap. No.* 2592, 211–18.—Predictions of the performance of internal gas-drive reservoirs have previously been on the assumption of uniform saturation throughout at any time, or zero pressure differential. The present investigation essentially utilizes a radial system flowing gas and oil in a succession of steady states. The procedure involves fixing the gas/oil ratio, pressure drawdown, and spacing. The saturation distribution calculated for the system permits the determination of stock tank oil removed from the system, while the pressure distribution gives the average pressure. The G.O.R. and average pressure must balance according to material balance concepts, and this balance is obtained by trial and error. A series of such calculations provides the reservoir history.

The details of the method of calculation are set out, together with tables summarizing the calculations. The results show that the variation of pressure and instantaneous producing G.O.R. with withdrawals is equivalent, for all circumstances calculated, to that determined using the simple equilibrium conditions. Hence it is concluded that the recovery from an internal gas-drive reservoir is a function only of the fluid and flow properties. The analysis ignores the economic rate at which withdrawals occur. Further calculations on productivity indices indicate that the history of an internal gas-drive reservoir is independent of the spacing or pressure drawdown. Again, economic limitations are ignored. G. D. H.

1004. A note on the valuation of relative permeability. O. F. Thornton. *Petrol. Tech.*, July 1949, **1** (7), 7.—In the flow of electricity through a partially saturated core the resistance is not a simple linear function of saturation. Thus the average length of path is not independent of saturation. Similarly, the length of path for fluid flow may not be independent of saturation. A relationship is derived from these considerations and the capillary pressure-effective permeability equation, and this suggests that a correction for tortuosity should be applied in calculating the relative permeability to a wetting phase. The correction factor may be obtained from the resistivity–saturation relationship. Calculated values for loose sands agree closely with observations when the above procedure is followed. G. D. H.

1005. Pilot gas injection—its conduct and criteria for evaluation. L. F. Elkins and J. T. Cooke. *Petrol. Tech.*, July 1949, **1** (7), *A.I.M.M.E. Tech. Pap. No.* 2646, 180–8.—Gas injection to increase oil recovery has been considered for most important discoveries during the past ten to fifteen years, but data are yet too limited to permit generalizations to be made with respect to effectiveness. Gas expansion from solution is effective in displacing oil at any point, but injected gas, following the path of least resistance, displaces oil from only a limited part of the reservoir, this part being determined by the permeability profile.

Pilot gas-injection tests give data on intake capacities and on the permeability profile. The case histories of pilot gas-injection tests are described. These are for a Lower Pennsylvanian sand, the San Andres and Grayburg limestones.

Eight gas-injection projects indicate that the recovery of oil is primarily due to

displacement. In one of the pilot gas-injection studies the results were confirmed on continued gas injection. The reservoir sweep efficiencies were quite low—some 10–20%—in the two cases where gas injection was at a rate and of a volume sufficient to allow reliable interpretation. It appears in these two cases that pressure maintenance would be inadvisable, and that reduction of pressure to permit expansion of gas in those parts of the reservoir unaffected by injected gas would be necessary to obtain oil therefrom.

In pilot injection tests the rate and period should be sufficient to give marked changes in produced gas/oil ratio. There should be adequate testing before and after injection to determine normal trends without injection. G. D. H.

1006. Bottom hole flow surveys for determination of fluid and gas movements in wells. C. R. Dale. *Petrol. Tech.*, Aug. 1949, **1** (8), *Tech. Pap. No.* 2644, 205–10.—A sensitive rotor which is turned by the passage of fluids through the housing is associated with a film-recording system which marks the rate of rotation. In flowing wells the device is run through the tubing; in pumping wells it is run between the annulus and the tubing. It is usual to make observations at a series of depths.

The results of a number of flow surveys are discussed in association with other types of measurements. The examples include a leaking bridge plug, a case of water entry, a well in which only the lower sands produce although others are open, simultaneous production from several sands, the location of gas entry, gas injection, and interval circulation. G. D. H.

1007. A method of imbedding large cores in plastic for fluid flow studies. *Petrol. Tech.*, Aug. 1949, **1** (8), 18–22.—Cores 24 in in dia and 30 in long have been embedded in Lucite, which is tough, fairly transparent, capable of being machined, impermeable, and inert to the gases and liquids used in oil-production studies. Lucite (methylmethacrylate polymer) absorbs small quantities of water.

The core is cleaned and fitted with electrodes and salt piezometric rings, which are held in place by Baker resin. A thin sealing layer of Baker resin is then put on the core. The coat is applied when almost stringy in consistency, and it must be even. The coat is polymerized at 70° C.

The moulding of the Lucite sheath is done in a cylindrical mould. ½-in-thick sheaths have proved satisfactory. Steel and aluminium moulds have been used, the latter needing a releasing agent, and the former none due to its mirror surface. Small blocks of Lucite wired to the core centre the core in the mould. The monomer–polymer dough is mixed by stirring 60% of polymer granules into 40% of monomer. When a " no-setting " state is reached the dough is transferred to the mould, 300 p.s.i. gas pressure is applied, and the mould is lowered until it is in the water-bath at 70° C. Cold water is circulated through a coil fitted closely round the mould. After 30 min the mould is lowered a further inch into the water-bath, the cold-water coil being raised so that it does not enter the bath. It is lowered two more inches at 30-min intervals and thereafter 1 in every 20 min. When the mould is kept at 70° C for 3 hr before being allowed to cool slowly.

The reaction is exothermic and accompanied by shrinkage. The solid ends of Lucite are sawn off to expose the core, and end plates, flow lines, pressure taps, and electrode connexions are fitted. The mounts are sensitive to temp change, a range of 10° C tending to destroy the bond between the Lucite and the sealing resin. Flowing pressures up to 100 p.s.i. have been used, and hydrocarbons without aromatics or unsaturateds, as well as dilute acids and salt solutions. G. D. H.

1008. Experiments on the capillary properties of porous solids. J. C. Calhoun, M. Lewis, and R. C. Newman. *Petrol. Tech.*, July 1949, **1** (7), *A.I.M.M.E. Tech. Pap. No.* 2640, 189–96.—Experiments have been carried out on water displacement from porous solids by air and various organic liquids, and also on the measurement of the lowering of v.p. of water within a porous solid with subsequent conversion of the v.p. data to capillary-pressure data. The capillary-pressure curve at high capillary pressures has been elucidated, and it is indicated that there is no " irreducible minimum," but that zero water saturation is reached at some finite value of capillary pressure. Caution should be observed in choice of displacing liq for determining connate water

values by capillary-pressure curves. It is also desirable to measure such values at a max pressure which is a considerable distance above the capillary-pressure plateau.

The capillary-pressure data are used to characterize the individual porous systems, and surface-area values are calculated from the displacement pressures, absorption data, and the Carman equation. The results indicate that different quantities are being measured by the different methods. G. D. H.

1009. Efficiency of gas (producing) wells without heating of the pipes after expansion. Z. Onyszewski. *Nafta*, Dec. 1948, **4**, 372–4.—Summarizes experimental results from exploitation of some French gas-bearing fields. The adiabatic expansion formula

$$\frac{t_1}{t_2} = \left(\frac{p_1}{p_2}\right)^{\frac{\gamma-1}{\gamma}} - \frac{\frac{t_1}{t_2} - 1}{\left(\frac{p_1}{p_2}\right)^{\frac{\gamma-1}{\gamma}} - 1}$$ is used.

For CH_4 $\frac{\gamma - 1}{\gamma} = 0{\cdot}22$

and $$\frac{t_1}{t_2} + 1 = \left(\frac{p_1}{p_2}\right)^{0{\cdot}22} + \left(\frac{p_2}{p_1}\right)^{0{\cdot}22}.$$

To lower the freezing point of water, alcohol is added. Expansion should be in stages, and the advantage is that a greater proportion of gasoline is obtained.

A graph and a table prove the point, and a flow diagram is provided. M. S.

1010. A new compressibility correlation for natural gases and its application to estimates of gas-in-place. E. B. Elfrink, C. R. Sandberg, and T. A. Pollard. *Petrol. Tech.*, Aug. 1949, **1** (8), *A.I.M.M.E. Tech. Pap. No.* 2642, 219–23.—Charts are presented which provide compressibility factors for use in both two-phase and single-phase hydrocarbon systems. In the use of these charts the attainable accuracy will be comparable to that obtained previously for single-phase systems. The correlation is based on 1030 compressibility measurements made on twenty-one hydrocarbon samples taken from eight oilfields. 75% of the data were from California, 15% from the Mid-Continent, and 10% from South America. Numerically the average deviation of the experimental data from the charts is 1·22%.

Tables give the properties of the systems used, a typical analysis, comparisons of calculated and experimental compressibility factors, comparisons of calculated and measured specific volumes for a condensate mixture, and comparison of single-phase and two-phase compressibility.

Examples of the use of the charts are given, together with a method of predicting the presence or absence of a liquid phase in a condensate system of known composition.

Graphs indicate the errors resulting from use of single-phase compressibility factors in the two-phase region and from omission of compressibility factors in volumetric estimates of reserves. G. D. H.

Oilfield Development.

1011. Crude oil production record for 1949 set in September. D. M. Duff. *Oil Gas J.*, 24.11.49, **48** (29), 52.—In September world crude oil production is estimated to have been 9,308,700 b.d. the U.S.A. giving 4,915,000 b.d. Venezuela had a record output of 1,426,500 b.d., Colombia gave 84,217 b.d., Mexico 175,000 b.d., and Canada 68,400 b.d.

Tables give the August and September outputs by countries, the Venezuelan output by fields and companies, and the monthly rates for major areas in 1949. G. D. H.

1012. 60,000-brl gain in Venezuela boosts world's crude output. D. M. Duff. *Oil Gas J.*, 20.10.49, **48** (24), 76.—In August world oil output outside Russia and eastern Europe averaged 8,973,700 b.d., the U.S.A. providing 4,761,000 b.d. The Venezuelan output was 1,378,000 b.d., while the Middle East gave 1,321,900 b.d., the lowest figure for 1949.

Tables give the July and August daily outputs by countries, the Venezuelan output by months for 1949, and the monthly figures for major areas. G. D. H.

1013. Foreign output shows decline in July ; world total off 2%. D. M. Duff. *Oil Gas J.*, 22.9.49, **48** (20), 145.—Outside Russia, Eastern Europe, and the U.S.A., the July 1949 daily output was 3,414,400 brl. The Saudi Arabian output was 401,000 b.d., 80,000 b.d. less than in June. Iran and Iraq showed increases over June. Canada and Venezuela, respectively, gave 58,200 b.d. and 1,307,000 b.d. in July. Russa and Eastern Europe are estimated to have given 743,400 b.d. in July.

Tables give the daily average outputs by countries for June and July, and the monthly trends for major areas. G. D. H.

1014. Foreign rotary—rig operations show further recent decline. Anon. *Oil Gas J.*, 6.10.49, **48** (22), 159.—Outside the U.S.A. 391 rigs were operating in September, exclusive of Russia, Germany, Japan, and Russian-controlled areas. Since March the number of rigs in Venezuela has declined from 138 to 93.

A table gives the numbers of rigs operating by countries for March, August, and September 1949. G. D. H.

1015. Deep-drilling trend continues. J. C. Reidel. *Oil Gas J.*, 20.9.49, **48** (20), 175.—The deepest well is in Sublette County, Wyoming, and reached 20,521 ft. In the first half of 1949, 541 wells were drilled below 10,000 ft in the U.S.A., while 1076 were completed between 7500 and 10,000 ft. Both these numbers were greater than for the first half of 1948.

Tables give the U.S. drilling and producing depth records by states and districts, and list the main deep areas of the U.S.A., with the estimated max thickness of sediments and the chances of finding oil in the deepest part. G. D. H.

1016. Reserves show greatest increase in 10 years. H. J. Struth. *Petrol. Engr*, Jan. 1949, **21** (1), A-27.—During 1948, 12,850 exploratory wells were drilled in the U.S., and reserves were increased by approx 1250 million brl, bringing the total reserves to approx 26,015 million brl. Discoveries per exploratory well were 213,000 brl, compared with 442,000 brl during 1940–42. C. A. F.

1017. More footage drilled with fewer rigs. J. C. Casper. *Oil Gas J.*, 22.9.49, **48** (20), 179.—Excluding the Appalachian and North Central districts of the U.S.A., 1904 drilling units were operating on an average during the first seven months of 1949. The total footage was 66,360,000 ft, an increase of 8·4% with forty-nine fewer rigs, over the same period of 1949. The average well depth was 3627 ft (3454 ft for 1948).

Tables give the footage drilled in each area and year from 1940 ; the footage drilled, new oil found, and the ratio of these figures. The Rocky Mountain area had the highest finding figure per foot, namely 66·6 brl/ft ; for the U.S.A. as a whole the figure was 24·8 brl/ft. G. D. H.

1018. Exploration sets record in 1949. Anon. *World Oil*, Feb. 1950, **130** (2), 74.—7452 exploratory wells were drilled in the U.S. in 1949. 674 new fields, and 284 new pays in known fields were discovered. 1949 showed a 4·5% increase in oil discoveries over 1948, although only 3·5% more wells were drilled.

A table shows the results of exploratory drilling in the U.S. in December 1949 and the cumulative for the year. C. A. F.

1019. Completions fall below 1948 record. Anon. *World Oil*, Feb. 1950, **130** (2), 34.—38,158 wells were drilled in the U.S. in 1949, and average depth per well was 3573 ft.

In the Appalachian region lessened demand and lower prices for crude caused a 40% reduction in drilling.

A table shows the well completions in the U.S. during December 1949 and the cumulative for the year. C. A. F.

1020. Standard claims world's deepest producing well. Anon. *Oil Gas J.*, 8.9.49, **48** (18), 36.—5 Mushrush in the Wasco field, Kern County, California, came in flowing by heads at 15,440–15,475 ft. It gave 96 b.d. of 40·7° oil with 480,000 cu. ft. of gas from the Eocene. G. D. H.

1021. Pickens Field, Mississippi. F. T. Holden. *Petrol. Engr*, Sept. 1949, **21** (10), B-13.—Geological and geophysical work was carried out in the Pickens area in 1940, and the discovery well, I R. E. Wilburn, produced on completion 1013 b.d. of 38° oil and 183 b.d. of salt water. Fifty-one producers had been completed to June 1947, and in June 1949 forty-three wells were producing at an average of 75 b.d/well.

The structure is a fault block upthrown to the southwest, with several associated *en echelon* normal faults, having a northwest–southeast strike. Dip of the faults increases with depth. Structural complications of the field caused hazardous exploitation, and the varying throw along fault strikes was chiefly responsible for the large number of dry holes drilled.

Production is from the Wilburn sand, which is uniform over the structure. It is hard and fine-grained, having an average porosity of 28% and permeability 400 mD. There is an active water drive, and cumulative production to May 1949 was 11,766,270 brl. C. A. F.

1022. Canada abandons experimental work on tar sand deposits. Anon. *World Oil*, Feb. 1950, **130** (2), 216.—The six-year experiment made to determine whether the tar sands at Abasand in Alberta could be profitably exploited has been abandoned, as results to date have not justified the expense involved. C. A. F.

1023. Wells drilled, depth total doubled in Alberta in 1949. Anon. *World Oil*, Feb. 1950, **130** (2), 216.—820 wells were drilled in Alberta in 1949, 454 more than in 1948. These include 244 wildcats and 576 development wells.

The wildcatting programme increased Alberta's reserve from 550 million brl at January 1949 to 1·2 billion brl at December 1949.

The Redwater field has 271 producing wells and an estimated reserve of 600 million brl from the D_3.

The Leduc field has 347 producing wells and an estimated reserve of more than 250 million brl.

1949 saw new discoveries at Normandville (Devonian), Stettler (D_2 and D_3), Casagama (Cretaceous), Devonian discoveries at Golden Spike, Bon Accord, and Excelsior, and Cretaceous discoveries at Whitemud and Campbell. Oil was found in the Viking sand at Joseph Lake, and in the Madison Lime at Barrhead. C. A. F.

1024. Operations in Trinidad. Anon. *Petrol. Engr*, Jan. 1949, **21** (1), B-44.—Exploitation practice in the Point Fortin–Parrylands and Penal areas is discussed.

At Point Fortin production is from the Miocene Cruse, which consists of calcareous clays with fine-grained stringer sands. Structures are traps formed by faulting and folding against the Los Bajos fault, which has a considerable horizontal displacement. Subsidiary faults may form effective barriers to lateral fluid movements. North of the main fault the beds are imbricated and steeply dipping, but to the south on the downthrown side, Pliocene beds dip gently southwards into the Erin Syncline. Paraffinic crude is produced from the Pliocene Morne L'Enfer, a coarse to fine-grained sandstone with occasional clay beds.

In the Penal field production is from the Oligocene Herrera sand and the Miocene Moruga sand. The structure is a buried plunging anticline of Oligocene beds unconformably overlain by the Miocene.

In the Cruse sands, initial reservoir pressures are 40–50% higher than hydrostatic, and production declines rapidly. Average initial production is 200 b.d.

In Penal the Miocene sands usually have low reservoir pressures and oil is pumped, but the Oligocene sands have initial pressures 80–100% higher than hydrostatic, and initial production may reach 1500 b.d.

In the Point Fortin–Parrylands area, erratic sand developments necessitate close spacing, but at Penal, in the Herrera, relatively wide spacing is used as the sands are more regular.

Production in the two areas averages 15,000 b.d. C. A. F.

1025. Chile's Spring Hill field has 16 producers from 29 tests. Anon. *World Oil*, Feb. 1950, **130** (2), 217.—Twenty-nine wells have been drilled in the Spring Hill field on Tierra del Fuego, of which sixteen are producing. The field is connected to a terminal on Gente Grande Bay in the Magellan Straits, having a capacity of 600,000 brl.

Field production averages 2000 b.d., with an optimum of 10,000 b.d. A refinery is to be built. C. A. F.

1026. World's southernmost oil field begins commercial production. Anon. *Oil Gas J.*, 10.11.49, **48** (27), 193.—After four years of development the Cerro Manantiales field began producing in October, giving about 1000 b.d. from four wells. There are fifteen oil wells and five gas wells, twenty-five wells having been drilled. Some wells have G.O.R.s of 3000–4000.

10 miles to the northwest the Angostura structure is being drilled, and two wells have been drilled on the Espora structure which is 7 miles north of Cerro Manantiales. One gave gas and distillate; the other was dry. Two wells at San Sebastian, 50 miles south of Cerro Manantiales, showed the formations to be tight. G. D. H.

1027. Schoonebeek—landscaped oil field. Anon. *World Oil*, Feb. 1950, **130** (2), 210.—During 1949, 3000 ft of hole was drilled in the Schoonebeek field on the Dutch–German border. Seventy-nine wells are on production, and two are drilling. Production is from the Lower Cretaceous Valanginian from approx 2500 ft. Total field production for 1949 was over 4 million brl of 24·8° oil at approx 12,000 b.d., the max efficient production rate. No further active drilling programme is planned.

Geophysical work in the area began in 1935, and subsequent exploratory wells showed a promising structure west of Coevorden, where operations were continued from 1937 to 1939. Sixty wells were drilled during the German occupation, and eighty-five have been drilled to date. C. A. F.

1028. Oilfield development. J. Coates. *Indian Min.*, Apr. 1949, **3** (2), 60.—The modern procedure for developing sandstone fields, such as have been found in the Indian Union, is briefly discussed. C. A. F.

Transport and Storage.

1029. Modern tanker construction. N. Carter. *Welding*, Mar. 1950, **18** (3), 100.—The paper is primarily a description of the welded m.v. *Staland*, with special reference to the use of corrugated plates for the transverse and longitudinal bulkheads. The general lay-out of the *Staland* is in keeping with modern tanker practice, and details of design are included. The use of corrugated plates is described in detail, and particular reference is made to the saving in steel wt by this practice. It is estimated that the use of corrugated plating results in a saving in steel of about 11½% (by wt) and that this figure could be further increased by the adoption of welded side longitudinals. A. S.

1030. Rapid gauging of cylindrical dished-end tanks by means of nomograms. J. Breuil. *Chim. et Ind.*, 1950, **63**, 147–50.—Four nomograms are given, of which the first two are used to obtain vol in a flat-end horizontal cylindrical tank and the remaining two give the vol contained in the dished portion; addition of the two results gives the total vol in tank with an accuracy of 1%. Calculations involved are explained. Range covered (metres) is up to dia 15, length 15, and width of dished portion 1. V. B.

1031. Piping for fuel oil tanks and fuel oil burners. E. F. Opperman. *Heating & Ventilating*, Feb. 1950, **47** (2), 76.—The paper supplied in detail practical information on the subject of piping for both domestic and industrial fuel-oil-burning installations. A number of drawings are given showing the piping lay-out for various types of installation. The piping lay-outs are presented for both the pressure-atomizing type and the horizontal rotary-cup burner, but the principles involved can be applied to other types. A. S.

1032. Flow of gas in pipe lines. H. C. Owen. *Oil Gas J.*, 9.3.50, **48** (44), 71.—Equations used by most engineers to calculate isothermal flow of natural gas in transmission lines disregard the deviation of the gas from the ideal gas laws.

An equation is now provided for use in calculating isothermal flow which evaluates the effect of the deviation very accurately and is almost as simple to use as most flow equations in use.

A problem is stated and four methods of solution given. G. A. C.

1033. Specification of pipe for refinery service. O. L. Lewis. *Oil Gas J.*, 9.3.50, **48** (44), 97.—The chemical composition of steels for piping, some specifications, and refinery applications are discussed.

For low-pressure gas or water transport an A.S.T.M. A-120 carbon steel with no chemical specification and no physical-test requirement will suffice.

An 106 Grade A specification with carefully specified chemical composition and physical-testing requirement should be used for temps above 750° F.

Chrome–molybdenum steels should be used for corrosive atmospheres or high creep strength required for 900° F to 1200° F operation.

For application above 1200° F or for corrosion-resisting service a steel of 18-chrome–8-nickel-range type 304 or similar should be employed. G. A. C.

1034. Planning modern gas-compressor stations. 1. T. G. Hicks. *Oil Gas J.*, 16.2.50, **48** (41), 92.—This is the first of a series of five articles on this subject, and concerns the foundations and buildings.

Wall and compressor foundations, soil condition, piling, and concrete mixtures are discussed.

Recommendation for water–cement ratios for concrete to meet different degrees of exposure are given. G. A. C.

1035. Planning modern gas-compressor stations. 2. T. G. Hicks. *Oil Gas J.*, 23.2.50, **48** (42), 183.—Part 2 discusses reciprocating compressors, valves, pressure ranges, and controls; centrifugal compressors, gas piping, sizing suction, and discharge lines; an actual problem is stated and solution given. The connexions to foundations are discussed. G. A. C.

1036. Planning modern gas-compressor stations. 3. T. G. Hicks. *Oil Gas J.*, 2.3.50, **48** (43), 73.—Well-planned auxiliary equipment to modern gas-compressors is essential to operation at rated capacity. The water-cooling system is one of the necessary items, and depends upon amount of water available, its quality, allowable temp rise, and type of piston-cooling system used in engine.

Where scale-forming water only is available for engine-cooling, the closed rather than the open system should be used unless water-treating materials are available. Amount of water which must be circulated can be calculated from knowledge of heat to be rejected by the engine to cooling water and allowable temp rise of the water.

Additional cooling for the lubricating-oil system and piston must be allowed for.

All piping runs should be short. G. A. C.

1037. Planning modern gas-compressor stations. 4. T. G. Hicks. *Oil Gas J.*, 9.3.50, **48** (44), 86.—In this instalment cooling equipment, air-filters, and exhaust systems are dealt with.

Cooling-water circulating pumps should be installed in duplicate; and single-stage centrifugal pumps, single- or double-suction types are suitable for water circulation. Raw-water pumps should be located at base of cooling tower, and jacket-water pumps as close as possible to units served.

Cooling towers are preferable to cooling ponds. Water treating is necessary, and methods include Zeolite, lime, soda, and dichromate processes.

Air filtration will increase operating time between reborings from 5 to 10 times that obtained with unfiltered air, but a filter should be carefully selected and applied.

A table shows recommended water characteristics for engine-cooling systems. G. A. C.

1038. Aspects of gas heat exchangers as applied to transmission-system problems. Anon. *Oil Gas J.*, 9.2.50, **48** (40), 84.—Means of dissipating and rejecting waste heat given off from power requirements in cross-country transmission of large quantities of natural gas through a pipeline system are discussed.

Points to be considered in using gas-exchangers include amount of cooling necessary to give desired dew point, temp level at which this cooling must take place, flexibility and simplicity of design, and costs compared with alternate proposals.

Definite advantages are to be obtained under correct conditions by rejecting heat load to gas stream, particularly when water scarcity is involved. G. A. C.

1039. Throttling effects of gate versus globe valves. T. W. Reynolds. *Heating & Ventilating*, Feb. 1950, **47** (2), 72.—The paper consists of a discussion on the relative merits of gate valves and globe valves to obtain throttling. A. S.

1040. Estimating water discharge. J. D. Constance. *Heating & Ventilating*, Feb. 1950, **47** (2), 89.—A method is given of calculating the approx water-discharge rates from fire hydrants, sludge lines, and similar exits. A. S.

1041. Multichannel microwave radio relay system for pipe-line communication. J. D. Munton. *Oil Gas J.*, 16.2.50, **48** (41), 88.—A micro-wave pulse time multiplex radio relay in the 1850–1950-megacycle range providing facilities for continuous unattended telephone, telegraph, telemetering, and remote control service on one R.F. channel has been installed by Keystone Pipe Line Co. to assist in operating their pipeline system in eastern Pennsylvania.

The radio relay enables max co-ordination between despatcher at sending end of a pipeline (which holds 2·5 million gal of liquid product, and may contain a variety of products ranging from fuel oil to high-octane gasoline), and operating personnel at pump stations.

A figure shows simplified block diagram of the relay system. G. A. C.

1042. Radio network proves successful in major refinery. G. Weber. *Oil Gas J.*, 2.3.50, **48** (43), 46.—The equipment and procedure with a radio network at the Bayway refinery of Esso Standard Oil Co. at Linden, N.J., is described.

Some thirty-three refinery vehicles are fitted with transmitter–receiver sets, allowing direct communication with despatch office at refinery.

The system is available at any time for an emergency call such as fire, explosion, or other serious matters.

The system is leased from and maintained by the New Jersey Telephones.

G. A. C.

1043. Patents. M. N. Lebedeff, assr to Chicago Bridge and Iron Co. U.S.P. 2,495,742, 31.1.50. Seal support for floating-roof tanks.

C. M. Orr and F. L. Goldsby, assrs to Chicago Bridge and Iron Co. U.S.P. 2,495,755, 31.1.50. Seal for floating-roof tanks.

I. L. Willmiller, assr to Chicago Bridge and Iron Co. U.S.P. 2,495,798, 31.1.50. A storage vessel for low-temperature liquids with inner and outer shell separated by an insulating space, the inner shell being able to move horizontally radially in or out.

C. F. S.

Refinery Operations.

Refineries and Auxiliary Refinery Plant.

1044. Revamping of refinery plant. W. R. Prentice and G. W. Loynd. *I.P. Review*, 1950, **4**, 49.—One of the main problems confronting the petroleum industry in this post-war period is to increase production and to improve the quality of its products despite the inevitable difficulties of equipment shortage. It has, therefore, been necessary to " revamp refinery plant " in a number of ways : (1) to overcome process problems which arise from time to time ; (2) to increase production ; (3) to reduce costs ; (4) to utilize plant for a different purpose ; (5) to eliminate superfluous equipment. A specific example of No. 4 is given by a description of the conversion of a plant in Oklahoma, which formerly produced 100-octane gasoline to one which fractionates 3000 tons a day of Oklahoma crude. R. H.

1045. Trends in refinery practice. M. A. L. Banks. *I.P. Review*, 1950, **4**, 58.—Trends in refinery practice are described, with particular reference to topping and cracking. The basic figures for yields and costs are applied to these trends. The underlying factor has been the increased demand in the U.S. for petroleum products which has led to the establishment in Europe of refineries for handling Middle East crude. Flexibility in refinery practice is necessary, and first steps taken in Great Britain are known as the Kettle development. Details of this and other developments are given. R. H.

1046. Work in progress at the new Shell Haven refinery. Anon. *Mech. World*, 3.3.50, **127** (3294), 247.—The paper described certain features of the new Shell Haven refinery. A 900-ft cooling-water tunnel is being built 50 ft below the River Thames, and this 9-ft-dia tunnel will carry water from the Thames to a large pump-house 30 ft below ground. Notable features of new plant include high degree of control by instrumentation and almost complete elimination of steam for operating pumping units, most of which will be electrically driven. Doctor-treating plant will provide facilities for treatment of about 1300 tons straight-run petroleum from distilling unit. Also installed will be pump- and weigh-house fully equipped for intensive T.E.L. blending. Various other features are described. A. S.

1047. Ethane and propane separation greatly simplified at Dubach. C. B. Ames and T. D. Tabbart. *Refiner*, May 1949, **28** (5), 117–26.—Detailed flow diagrams are given of a new gasoline plant. Low-mol.-wt. absorber oil is used, and the mixture of oil and wet gas is refrigerated and dehydrated before entering the high-pressure absorbers. 80% propane extraction is achieved. The vol of circulating oil is small, with consequent reduction in oil coolers, vent tanks, and pumps. The oil-stripping temp has been reduced to 410° F. W. E. M.

1048. Crude-oil capacity at Midland Co-operative plant stepped up 50%. R. B. Tuttle. *Oil Gas J.*, 16.2.50, **48** (41), 105.—Revisions in the processing lay-out of the Cushing Okla refinery of the Midland Co-operative Wholesale have resulted in a throughput of 6500 brl of crude oil daily.

Major revisions involved addition of a 6 × 45-ft preflash tower and heat-exchange equipment, with new kerosine stripper. A second reaction chamber was incorporated into the existing cracking plant to increase input by 20%. G. A. C.

1049. Canary Islands refinery adding modern lube-manufacturing facilities. Anon. *Oil Gas J.*, 9.2.50, **48** (40), 89.—A brief account of the scheduled lubricating-oil production at the Tenerife refinery of Compania Espanola de Petroles is given. Capacity will be 400 brl of finished products daily.

Current crude-oil distillation capacity is to be increased by 35% to 13,500 b.d., and a propane-fractionating unit is scheduled for erection early in 1950. G. A. C.

1050. Economics of motor voltage selection. E. T. Horridge. *Refiner*, May 1949, **28** (5), 133–9; July 1949, **28** (7), 157–61.—The theoretical and practical advantages and disadvantages of commonly used motor voltages are discussed. Data are given on the costs of most types of motors, cost of installation, running costs, and overhauls. It is concluded that up to 100 h.p., 440 V is the optimum figure, assuming that the feeders and motor leads are not excessively long. Assuming that distribution circuits are less than 4000 ft, that circuit loadings are less than 1500 kVA, and that most of the load is associated with loads above 100 h.p., the optimum voltage is 2300 V. At very high loadings, 4000-V motors are most suitable. W. E. M.

1051. Techniques in investigation of fluid flow. W. Leaf and L. C. Atchison. *J. phys. & colloid Chem.*, 1949, **53** (6), 960–6.—A brief description of the method of applying colloidal-clay suspensions to certain fluid-flow problems. D. F. J.

1052. The testing of boilers. L. J. Hayden. *Trans. Inst. mar. Engrs*, Feb. 1950, **62** (2), 85.—Admiralty boiler tests are described and discussed, and typical test results are given which indicate the characteristics of a water-tube boiler under test. Methods

used for making the various measurements involved in boiler testing are described and illustrated and figures given for the errors involved. To check the efficiency as measured, an estimation should be made of the heat balance, and a summary is given of the heat losses which are encountered. Problems of test measurement are described, and attention given to the practical difficulties involved in the measurement of temperature, pressure, moisture, circulation, velocity, dust emission, and gas analysis.

A. S.

1053. Patents. F. D. James. U.S.P. 2,493,969, 10.1.50. A heat exchanger of the shell and tube bundle type having an anti by-passing shield construction.

C. E. Hemminger, assr to Standard Oil Development Co. U.S.P. 2,494,337, 10.1.50. Describes the apparatus used for contacting finely divided solid particles with gaseous materials.

A. C. Skooglund, assr to Standard Oil Development Co. U.S.P. 2,494,588, 17.1.50. An extruder reactor for producing solid polymers of *iso*butylene.

M. I. Dorfan. U.S.P. 2,495,512, 24.1.50. Bubble tower.

O. Spring, assr to Danciger Oil and Refining Co. U.S.P. 2,495,665, 24.1.50. An apparatus for producing acetylene by incomplete combustion of hydrocarbons.

C. F. S.

Distillation.

1054. Principles of extractive distillation. E. G. Scheibel. *Chem. Engng Prog.*, 1948, **44** (12), 927.—Basic principles of extractive distillation are discussed, together with a method for solvent selection. Methods for the estimation of azeotrope formation and for the evaluation of the efficiency of different solvents are presented. An approx method for the design of extractive distillation processes is described, with factors outlined in favour of vapour feed and indicating the effect of prefractionation of such feed.

J. G. H.

1055. Phase relations for petroleum fractions. W. C. Edmister and D. H. Pollock. *Chem. Engng Prog.*, 1948, **44** (12), 905–26.—The use of phase conditions of petroleum fractions in the process design of refining equipment and their prediction by empirical correlations based on experimental equilibrium flash-vaporization data are remarked, and details are given of equilibrium flash-vaporization runs made on twenty-seven typical refinery stocks, twenty-one of these runs being made at atm pressure only, with the remaining six at various pressures up to 200 p.s.i. gauge. In addition, A.S.T.M. distillations were obtained on the equilibrium vapour and liquid from runs on nine stocks, with true b.p. distillation data for six of these and for six additional stocks.

Using this new data in conjunction with all data available from the literature, an empirical method of predicting the equilibrium flash-vaporization curves of petroleum fractions at various pressures is presented with applications to the design of distillation equipment.

J. G. H.

1056. Fractionating column calculations on the basis of heat effects. F. J. Zuiderweg. *Ingenieur*, 3.3.50, **62** (9), Ch. 19.—The calculation of the theoretical number of plates in a fractionating column by equations based on heat balance rather than vapour/liquid equilibrium relationship is discussed very briefly. A number of equations are given, and one by van Wijk is considered to be the best. (Dutch and German references provide the author's sources of information.)

R. R.

1057. Effect of sound waves on fractional distillation. C. C. Coffin and B. L. Funt. *J. phys. & colloid Chem.*, 1949, **53** (6), 891–94.—Standing ultrasonic waves in short unpacked distillation columns have been found to give increased separation of a volatile mixture. This effect is not produced only by the increased mechanical disturbance of the liq phase.

D. F. J.

1058. Fractional liquid extraction. E. C. Schiebel. *Chem. Engng Prog.*, 1948, **44** (9), 681–90; 1948, **44** (10), 771–82.—Operating data is presented on a new design of liquid-extraction equipment consisting of a liquid-extraction column with alternate calming

and mixing sections and a centrally located shaft carrying agitators fitted with vertical blades. The heavier liq is introduced at the top of the column and flows downwards meeting the lighter liq which has been introduced at the bottom. It is claimed that it is possible to obtain better than 100% efficiency per actual stage because of additional countercurrent contacting between the actual stages. Experiments on a 1-in column indicate that the design lends itself readily to the construction of larger dia columns.

Data on the separation of isomers, of different members of a homologous series of compounds and a different type of compounds are presented. Methods for predicting the necessary liquid-distribution data and for calculating column performance are also described, together with the use of the column for simple liq extraction.

J. G. H.

1059. Influence of reduced pressure on the separating capacity of packed columns. F. J. Zuiderweg. *Ingenieur*, 3.3.50, **62** (9), Ch. 20.—This article is but a critical survey of work carried out in this field by investigators whose papers have been published in *Industr. Engng Chem.* For example, the fall in efficiency of a column when operated under vacuum is explained by the fact that the system is working at a lower temp, which leads to an increase in the visc of the liq phase. This in turn causes an increase in the liq-phase film resistance, and a consequent reduction in the rate of material transfer. R. R.

1060. Heat, mass transfer of gas film in flow of gases through commercial tower packings. R. G. Taecker and O. A. Hougen. *Chem. Engng Prog.*, 1949, **45** (3), 188–93.—Mass and heat-transfer factors are presented for the gas film in air flowing through Raschig rings, partition rings, and Berl saddles, the data being obtained by the measurement of the rate of evaporation of water into a stream of air from wetted packings during the constant drying-rate period. The packings were constructed of a special clay–kieselguhr mixture in order to produce a solid with high porosity and high capillarity to act as a reservoir for water and to bring the water rapidly to the surface during the constant-rate period. For Berl saddles the values of mass-transfer factors averaged about 30% higher than for the Raschig rings. While the entrance effects of the bed on the gas stream did not alter appreciably the transfer factors, the effect of the flowing liq upon the gas-film coeff for use in scrubbers and dist columns has yet to be investigated. J. G. H.

1061. Patents. A. E. Handlos and G. J. Pierotti, assrs to Shell Development Co. U.S.P. 2,496,207, 31.1.50. Describes the azeotropic distillation of hydrocarbons from sulpholanes, the azeotroping agent being an aliphatic alcohol.

R. C. Woerner, assr to Sinclair Refining Co. U.S.P. 2,494,274, 10.1.50. An improvement in an extractive distillation process utilizing nitrobenzene as a selective solvent, by controlling build-up in the circulating solvent by withdrawing solvent from the system, diluting with non-aromatic raffinate, removing precipitated solids, and returning to the system. C. F. S.

Absorption and Adsorption.

1062. Redistribution of adsorbate by diffusion. E. Ledoux. *J. phys. & colloid Chem.*, 1949, **53** (6), 960–6.—The efficiency of dynamic adsorption in a bed which is started up after an interruption in the adsorption cycle depends considerably on the distribution of adsorbate in the bed. This, in turn, depends upon the redistribution of adsorbate during the period of idleness. A semigraphical procedure for plotting the v.p. and concn curves is presented which enables the determination of the diffusivity for any system. D. F. J.

Solvent Extraction and Dewaxing.

1063. Patents. A. P. Lien, B. L. Evering, assrs to Standard Oil Co. Indiana. U.S.P. 2,495,850, 31.1.50. A method of extracting aromatic hydrocarbons from a mixture of liquid aromatic and non-aromatic hydrocarbons, by extracting at a temperature 50° F to about 150° F with a complex of boron fluoride with an oxygenated alkane compound.

A. P. Lien, B. L. Evering, assrs to Standard Oil Co. Indiana. U.S.P. 2,495,851, 31.1.50. Desulphurization of organic substances by extracting at a temperature 50° F to about 150° F with a solvent comprising a complex of boron fluoride with an oxygenated alkane compound.

E. R. Gilliland, assr to Standard Oil Development Co. U.S.P. 2,495,842, 31.1.50. The fractionation of gases with solid adsorbents. C. F. S.

Cracking.

1064. Regeneration characteristics of clay cracking catalyst. J. C. Dart, R. T. Savage, and C. G. Kirkbride. *Chem. Engng Prog.*, 1949, **45** (2), 102–10.—Spent clay cracking catalyst is regenerated by burning off the carbonaceous deposit in the presence of air. The design and operation of an experimental regeneration unit is described, and, from the data so obtained, correlations are established between instantaneous carbon content, combustion temp, and oxygen partial pressure. From the relationships so established an equation is derived which, involving only the three primary variables mentioned, facilitates the calculation of the instantaneous carbon-burning rate at any design condition, together with the coke-burning rate, this latter calculation being derived from the relationship between the fractions of hydrogen and carbon burned. J. G. H.

1065. Heat of cracking and regeneration in catalytic cracking. J. C. Dart and A. G. Oblad. *Chem. Engng Prog.*, 1949, **45** (2), 110–18.—Previous methods of obtaining heat of reaction data are discussed, and their weaknesses indicated as compared with a new method employing calorimetric apparatus. The equipment and procedure are described, and the results so obtained are contrasted with data obtained by other methods. J. G. H.

1066. Economics of moving bed catalytic cracking processes. T. A. Burtis, J. C. Dart, C. G. Kirkbride, and C. C. Peavy. *Chem. Engng Prog.*, 1949, **45** (2), 97–101.—An economic comparison between the conventional moving-bed Thermofor catalytic-cracking process and the recent Houdriflow process. It is concluded that the Houdriflow design shows substantial savings in investment, utility, and maintenance costs with higher catalyst costs due to catalyst losses, these depending on the catalyst-to-oil ratios chosen. These higher catalyst costs may, however, be outweighed by a probable increase in equilibrium catalyst activity. J. G. H.

1067. Various refinery applications of Houdriflow cat cracking. C. C. Peavy, W. Weinrich, G. F. Hornaday, and H. D. Noll. *Refiner*, June 1949, **28** (6), 117–23.—This paper re-examines the economics of the four major cracking processes, thermal, vacuum, visbreaking, and coking. W. E. M.

1068. Patents. H. H. Voge, G. M. Good, and B. S. Greensfelder, assrs to Shell Development Co. U.S.P. 2,495,648, 24.1.50. A process for treating olefins with cracking catalyst of the group consisting of silica–alumina, silica–magnesia, silica–zirconia–alumina and alumina–boria, and the activated-clay cracking catalysts.

H. A. Hormann, assr to Houdry Process Corpn. U.S.P. 2,495,723, 31.1.50. Liquid-phase cracking of hydrocarbons with water-saturated catalysts under mild reaction conditions including a catalyst-bed temperature of 200–700° F.

G. A. Mills and E. B. Cornelius, assrs to Houdry Process Corpn. U.S.P. 2,495,751, 31.1.50. Conversion of hydrocarbons with modified clay catalysts under catalytic-cracking conditions.

L. F. Strader, assr to Houdry Process Corpn. U.S.P. 2,495,786, 31.1.50. Prevention of afterburning in a moving-bed catalyst-regeneration process by passing coked catalyst down through a number of combustion zones which are supplied with air and to which steam is added to various zones.

H. A. Shabaker, assr to Houdry Process Corpn. U.S.P. 2,494,586, 17.1.50. A process for cracking hydrocarbons with a modified kaolin catalyst.

H. W. Grote, assr to Universal Oil Products Co. U.S.P. 2,494,614, 17.1.50. A process and apparatus for the regeneration of fluidized catalyst.

W. S. Bonnell, assr to Gulf Oil Corpn. U.S.P. 2,494,794, 17.1.50. Process of hydrocarbon treatment and regeneration of the catalyst.

P. C. Keith, assr to Hydrocarbon Research Inc. U.S.P. 2,495,262, 24.1.50. Catalytic treatment of hydrocarbons and regeneration of catalyst in stationary beds.

R. J. Hengstebeck, assr to Standard Oil Co. Indiana. U.S.P. 2,493,917, 10.1.50. A catalytic conversion process where the contaminated catalyst is immersed in a liquid for removing contaminants but which is inert with regard to the catalyst.

C. F. S.

Polymerization.

1069. Patents. E. Arundale, assr to Standard Oil Development Co. U.S.P. 2,494,326, 10.1.50. An improvement in the manufacture of synthetic rubber-like materials by emulsion polymerization, using 0·125–1·0% of an aliphatic mercaptan mixture as the modifier.

E. C. Hughes and H. M. Stine, assrs to The Polymerization Process Corpn. U.S.P. 2,494,510, 10.1.50. The polymerization of propylene in the presence of *iso*butane and using a copper pyrophosphate catalyst to produce liquid hydrocarbons useful as a motor-fuel component.

M. Naps, assr to Shell Development Co. U.S.P. 2,494,517, 10.1.50. Granular polymerization of vinyl chloride.

J. S. Saylor, assr to Standard Oil Development Co. U.S.P. 2,494,585, 17.1.50. The copolymerization of *iso*- and polyolefins in the presence of fluorine compounds and using a Friedel–Crafts catalyst.

G. P. Rowland, Jr., assr to The Firestone Tire & Rubber Co. U.S.P. 2,495,137, 17.1.50. The polymerization of butadiene by coating a surface with a solvent cement of a previously formed polymer of butadiene, evaporating the solvent to leave a polybutadiene coating, and contacting with gaseous butadiene to polymerize the butadiene.

W. D. Spaulding and B. K. Wasserdrug, assrs to National Steel Corpn. U.S.P. 2,496,107, 31.1.50. A process for the recovery of *cyclo*pentadiene from by-product coke-oven light oil by first separating a fraction having a boiling range of *cyclo*pentadiene and then polymerizing.

C. F. S.

Alkylation.

1070. Patents. F. E. Frey, assr to Phillips Petroleum Co. U.S.P. 2,494,867, 17.1.50. Hydrogen fluoride catalyst is used in the catalytic conversion of hydrocarbons and purified hydrogen fluoride is subsequently recovered.

A. Gislon, assr to Compagnie Française de Raffinage. U.S.P. 2,495,323, 24.1.50. A process for the alkylation of a mono-cyclic aromatic hydrocarbon with an olefin, using metal chloride and Friedel–Crafts catalysts, to produce products containing alkylated aromatic compounds.

C. F. S.

Chemical and Physical Refining.

1071. Prediction of reaction equilibria. R. R. Wenner. *Chem. Engng Prog.*, 1949, **45** (3), 194.—The application of data obtained from the analysis of reaction equilibria to process development and design is remarked, and a summary of sources of data and of methods for their use in the prediction of reaction equilibria is presented, together with a review of methods of estimating various items of thermodynamic data not directly determined by experiment.

J. H. G.

1072. Bender lead sulfide treating process. I. T. Fritz. *Oil Gas J.*, 23.2.50, **48** (42), 180.—The kerosine-sweetening system at the Marcus Hook plant of Sinclair Refining Co. is described.

A slip stream of kerosine is pumped through pots of crude rock sulphur and ammonia introduced according to volume and mercaptan content of stock to be treated; six lead-sulphide treating towers are operated in parallel.

G. A. C.

Special Processes.

1073. The chlorination of petroleum hydrocarbons. G. W. Hearne. *Oil Gas J.*, 23.2.50, **48** (42), 163.—The chlorination of the saturated hydrocarbons is explained by a chain mechanism initiated by light, temperature, catalysts or the simultaneous occurrence of another chlorination reaction. Low-temp reactions are greatly retarded by the presence of oxygen; and reactivity of normal hydrocarbons appears to increase with increasing length of carbon chain. Presence of chlorine atoms in the hydrocarbon causes a decrease in reactivity.

The reactions of the unsaturated hydrocarbons differ mainly in that they occur in the liq phase in the absence of light and catalyst, a polar mechanism resulting in either vicinal dichlorides by addition or allylic chlorides by substitution. G. A. C.

1074. A study of fluidization of an iron Fischer–Tropsch catalyst. M. Leva, M. Grummer, M. Weintraub, and H. H. Storch. *Chem. Engng Prog.*, 1948, **44** (9), 707–16.—Earlier studies on fluidization with silica-sand beds are reviewed, and data are presented on the fluidization of a typical fused-iron Fischer–Tropsch catalyst of a considerably more irregular nature than sharp sand varying in size from 32 to 325 mesh. The data so obtained are in substantial agreement with earlier correlations, when allowance is made for the greater irregularity of the particles.

Application of the correlations to process design is discussed, and emphasis placed on the correct valuation of the physical properties of the reaction mixture.

J. G. H.

1075. Patents. G. J. Carlson, assr to Shell Development Co. U.S.P. 2,494,034, 10.1.50. The production of unsaturated halides by (*a*) mixing a symmetrical bis(2-alkenyl) ether with an excess of a hydrogen halide, (*b*) reacting the ether in liquid phase with the halide in ratio halide : ether not less than 2 : 1, at reaction conditions and in the presence of cuprous halide catalyst.

K. F. Dutson, assr to Standard Oil Development Co. U.S.P. 2,494,335, 10.1.50. Describes a method of producing high-purity *n*-heptane using a naphtha containing *n*-heptane and hydrocarbons having similar boiling points and including methyl-*cyclo*hexane.

E. F. Wadley, assr to Standard Oil Development Co. U.S.P. 2,494,371, 10.1.50. A method for removing oxygenated organic compounds from hydrocarbons by mixing the contaminated hydrocarbons with a solution of an alkali metal hydroxide in anhydrous methyl alcohol, and then treating with an alcoholic solvent.

C. G. Kirkbride and T. A. Burtis, assrs to Texas A. & M. Research Foundation. U.S.P. 2,494,392, 10.1.50. A process and apparatus for removing salt water from petroleum emulsions by passing the emulsion at 200–400° F through beds of glass fibres.

E. V. Fasce, assr to Standard Oil Development Co. U.S.P. 2,494,546, 17.1.50. Separation of olefins using a cuprous ammonium salt solution at a temperature between −29° C and 38° C, and pressure from atmospheric to 200 p.s.i.

G. F. Hornaday, assr to Houdry Process Corpn. U.S.P. 2,494,556, 17.1.50. Describes the treatment of clay catalysts used for the conversion of sulphur-containing feedstocks to improved motor fuel.

W. H. Smyers and D. W. Young, assrs to Standard Oil Development Co. U.S.P. 2,494,592, 17.1.50. Process and products obtained by treating synthetic polymers with phosphorous and sulphur.

F. R. Fisher, assr to Sinclair Refining Co. U.S.P. 2,494,695, 17.1.50. Petroleum coke is produced by pyrolytic conversion of hydrocarbons.

H. D. Hartough and J. J. Sardella, assrs to Socony-Vacuum Oil Co. Inc. U.S.P. 2,494,758, 17.1.50. Method for producing resinous materials by condensation of aldehydes (formaldehyde) with aromatics of thiophenes in the presence of glauconite.

J. A. Ridgeway, Jr., assr to Pan American Refining Corpn. U.S.P. 2,495,133, 17.1.50. The process of treating a heavy hydrocarbon oil with hydrofluoric acid.

J. E. Nickels, assr to Koppers Co. Inc. U.S.P. 2,495,278, 24.1.50. A process of dehydrogenating alkyl aromatic hydrocarbons by vaporizing the hydrocarbon, mixing the vapours with steam, and passing the mixture through a bauxite and alkali metal carbonate catalyst.

E. E. Van Andel, assr to Shell Development Co. U.S.P. 2,495,489, 24.1.50. The improvement to the process for the preparation of *n*-halo derivatives of organic sulphonamides from *p*-toluene sulphonamide.

H. Pines and B. Kvetinskas, assss to U.O.P. Co. U.S.P. 2,495,904, 31.1.50. Production of aromatic keto alcohols by reacting oxygen and an alkyl aromatic ketone at a temperature from about 50° to 250° C with an oxidation catalyst comprising a metal having an atomic number from 23 to 30 inclusive.

J. Overhoff and H. W. Huyser, assrs to Shell Development Co. U.S.P. 2,496,226, 31.1.50. The production of dispersions of reaction products of halogenated paraffins and alkaline polysulphides by reacting a di-halogen substituted paraffin with an alkaline polysulphide in aqueous medium with a dispersion agent consisting of a water-soluble salt of a sulphuric acid ester of a mono-hydric aliphatic alcohol.

H. Eilers, J. Overhoff, and J. C. Vlugter, assrs to Shell Development Co. U.S.P. 2,496,227, 31.1.50. The production of dispersions of reaction products of halogenated paraffins and alkaline polysulphides by the interaction of a dichloro-substituted paraffin with an alkaline polysulphide in aqueous medium with a dispersing agent, comprising adding an inorganic electrolyte providing a multivalent action to the aqueous reaction product, thereby effecting flocculation. C. F. S.

Metering and Control.

1076. Method for measuring the mass rate of flow of liquid or gas streams in closed transport lines. F. C. L. van Vugt. *Ingenieur*, **62** (8), O.5.—The author indicates the need for industrial instruments capable of measuring the mass rate of flow of fluid streams in closed transport lines, because, by such measurement, the accuracy of the time integral involved (*i.e.*, the product of the mean density, mean velocity, and time) is independent of possible rapid fluctuations in the density or velocity of the stream.

For experimental purposes, two prototype mass flow-meters for liquids have been developed. Their operation is as follows: the original stream is temporarily divided into two equal parts, and a circulating stream of constant speed is added to both parts in such a way that a constant velocity is added to one of them and subtracted from the other. The variable measured is the difference in the static pressure of the two streams.

Test results of the second meter showed the required lineal relation between the pressure differential and the mass rate of flow in the line, whether operating under stationary or pulsating conditions of flow. R. R.

Safety Precautions.

1077. An introduction to modern fire control. G. F. Prussing. *Oil Gas J.*, 2.3.50, **48** (43), 59.—A number of disasters in the petroleum industry in California during the past twenty-five years are discussed, and improvement of plant design traced to the present-day concept that errors of operational judgment must be expected and guarded against.

Modern technology of fire control is based on use of water fog as a cooling agent, the technique protects both men and exposed equipment from the heat of the fire.

Every plant operator should be fully instructed in use of fire-control methods.

G. A. C.

1078. Skin cancer in the engineering industry from the use of mineral oil. C. N. D. Cruikshank and J. R. Squire. *Brit. J. Industr. Med.*, 1950, **7**, 1–11.—Machine-shop workers are exposed to considerable skin contamination with cutting oil, due to oil spray. Examination of 138 men (three factories) showed oil folliculitis (on extensor surfaces of limbs) in 80%. No evidence of acquired immunity was obtained. Hyperkeratoses, considered a danger signal as possible cancer precursor, were observed in

33% of the workers examined. Records of scrotal cancer in the Birmingham area indicate that this can occur in engineering industry employees exposed to oil. Biological tests with a used cutting oil (no details) showed this to be non-carcinogenic to mice, but to cause benign tumours in rabbits. Pending further knowledge of biological properties of various oils prophylactic measures (protective clothing, regular medical inspection) are recommended. V. B.

PRODUCTS.

Chemistry and Physics.

1079. Adsorption studies. Physical adsorption of nitrogen, toluene, benzene, ethyl iodide, hydrogen sulphide, water vapour, carbon disulphide, and pentane on various porous and non-porous solids. B. L. Harris and P. H. Emmett. *J. phys. & colloid Chem.*, 1949, **53** (6), 811–25.—Adsorbents used were several glasses, two iron catalysts, and silver. Their surface areas were measured by N_2 adsorption. All isotherms were interpreted by both the BET and Hawkins–Jura (HJ) equation. It was found, however, that both the value of k employed in the HJ method, and the molecular areas required by the BET method varied considerably for adsorbates other than N_2 on different adsorbents. D. F. J.

1080. Adsorption of sodium myristate by carbon black. M. A. Reade, A. S. Weatherburn, and C. H. Bayley. *Canad. J. Res.*, 1949, **27F** (11), 426–8.—The adsorption, by a series of carbon blacks and an activated charcoal, of sodium myristate from 0·1% aqueous soln has been measured at 70° C by shaking a weighed amount of the carbon with the solution, filtering, and determining the fatty acid and alkali content of the filtrate. Preferential adsorption of fatty acid was observed in all cases. The extent of adsorption of both fatty acid and alkali increased with increasing surface area of the carbon. D. F. J.

1081. New method for the separation of hydrocarbons by selective adsorption. M. Godlewicz. *Nature*, 1949, **164**, 1132.—When mineral oil dissolved in light petroleum is percolated through silica gel containing trinitrobenzene, a red zone is obtained at the top of the column, blending into yellow in the middle, and the bottom is colourless. Hydrocarbons in the different zones can be collected separately and clear-cut fractions can be obtained.

The following fractions have been isolated from mineral oil: (1) a colourless fraction from the bottom zone containing saturated hydrocarbons; (2) a colourless or yellow fraction from the yellow–orange zone, eluted by a large excess of *n*-hexane and consisting of partially-hydrogenated aromatic rings; (3) a yellow to deep brown fraction from the red zone by eluting with benzene, and containing aromatics; (4) a dark-coloured solid by eluting with methyl ethyl ketone, consisting of resins. The second fraction can be subdivided into further fractions by the use of other indicators such as trinitro-toluene or -phenol. It will be noted that the first fraction consists of high-quality lubricants, whilst the third and fourth fractions contain the compounds usually removed during refining processes.

The method can also be applied to distillates and residues, commercial lub-oils, etc. H. C. E.

1082. Seven liquid phases in equilibrium. J. H. Hildebrand. *J. phys. & colloid Chem.*, 1949, **53** (6), 944–7.—A system of seven liq phases in equilibrium has been produced. The liquids are heptane, aniline, water, perfluorokerosine, white phosphorous, gallium, and mercury. Their immiscibility is explained in terms of the differences in the intermolecular force fields involved. D. F. J.

1083. Low temperature vapour–liquid equilibria: 1-phase equilibria in natural gas at low temperatures. Anon. *Chem. Engng Prog.*, 1949, **45** (2), 139–42.—Vapour–liquid phase equilibria for the common components of a natural gas were determined experimentally by a flow process at a total pressure of 100 p.s.i. and at a temp of −130 to 240° F, the equilibrium cell and its contents being maintained at low temps with

liquid nitrogen. The experimental equilibrium constants so obtained are compared with a correlation obtained from other data available in the literature. J. G. H.

1084. Estimation of liquid diffusion coefficients. C. R. Wilke. *Chem. Engng Prog.*, 1949, **45** (3), 218–24.—A method for the estimation of liq diffusion coeff is presented based on the relations suggested by the Eyring theory of absolute reaction rates and the Stokes–Einstein equation, and the effect of concentration on the diffusion coeff is briefly treated. Observed data for the diffusion of various substances in water, methyl alcohol, benzene, and fourteen miscellaneous solvents, comprising a total of 178 experiments have been reproduced by the method, with an average deviation of 10% between calc and observed values. J. G. H.

1085. Partial enthalpies of light hydrocarbons. H. F. Peters. *Refiner*, May 1949, **28** (5), 109–16.—This paper presents accurate data for methane, ethane, ethylene, propane, and propylene in hydrocarbon mixtures. Enthalpy is plotted as a series of curves against temp, with pressure as parameter. W. E. M.

1086. The slow oxidation of gaseous methyl ethyl ketone. J. Bardwell and C. Hinshelwood. *Proc. Roy. Soc.* A, 7.3.50, **201** (1064), 26–39.—The kinetics of the reaction between oxygen and gaseous methyl ethyl ketone have been investigated in the range 250–450° C. The anomalous temperature coefficient of the rate offers a good example of the transition from a low-temperature mode of oxidation to a high-temperature mode.

In the low-temperature range the rate of oxidation varies steeply with the initial pressure of the butanone, and is a very unusual function of the oxygen pressure, passing through a sharp maximum at certain pressures above which the rate falls and then tends to become constant. The max tends to disappear as the temp is raised. Increase of the surface/volume ratio causes a diminution in rate, while addition of inert gases has no appreciable influence.

The various complex relationships are well accounted for in their general form by a modification of the theory previously applied to pentane and hexane. This theory postulates a series of reaction steps of max simplicity, permitting a slow branching of chains by fission of peroxides. It leads to a rate expression which according to circumstances may become infinite at certain critical concentrations or remain finite throughout. The critical limits may be related to explosions or cool flames. In the application to butanone oxidation the peculiar form of the dependence of rate on oxygen pressure may be accounted for and a general account given of the observed cool-flame limits. W. H. C.

1087. The kinetics of the thermal decomposition of normal paraffin hydrocarbons. II. Comparative measurements on the series from propane to *n*-decane. F. J. Stubbs and C. Hinshelwood. *Proc. Roy. Soc.* A, 7.3.50, **201** (1064), 18–26.—Measurements over a range of pressures have been made of the rates of nitric oxide-inhibited decompositions of hydrocarbons in the series propane to *n*-decane (which according to the results of Part I represent the chain-free molecular reactions).

As inferred from the " apparent chain length " the molecular rearrangement process increases in importance relatively to the chain reaction with the ascent of the series, and, for a given hydrocarbon, with increasing pressure.

For each hydrocarbon, the order of reaction varies between the first and second. The results are not consistent with a constant order of 1·5, as has been suggested, and the pressure dependence is not consistent with the uniform transition from second order to first predicted for unimolecular reactions dependent upon a single mode of activation by collision. There appears to be a contribution to the overall reaction from processes which remain of second order up to high pressures. The decomposition rate for a given hydrocarbon pressure tends to a limit as the series is ascended, for reasons which are discussed. W. H. C.

1088. Cyclo-polyolefino and related molecules. W. Baker. *Endeavour*, 1950, **9**, 35.—A review of recent work on certain cyclic conjugated compounds other than those which are benzenoid in character. These include *cyclo*butadiene and diphenyline,

cyclo-octatetraene and derivatives, certain bicyclic systems, the azulenes, and various cyclic meso-ionic compounds.

Recent research has shown that many of the latter class of compounds had been wrongly formulated; for some no single formula is adequate. Twenty-six references.
R. V. W.

1089. Parachor of benzene and homologues of benzene. R. E. Donaldson and R. Q. Osborn. *J. Amer. chem. Soc.*, 1950, **72** (1), 35–6.—The parachors of benzene and twenty homologues have been calculated using the equation $P = \gamma^{\frac{1}{4}}[M/D\text{-}d]$ at 20°, 30°, and 40° C. The necessary surface-tension measurements were made by the maximum-bubble-pressure method using a modified bubbler (Quayle and Smart, *J. Amer. chem. Soc.*, 1944, **66**, 1935). It was noted that the parachors for *o*-, *m*-, and *p*-isomers differed from one another in the direction *o*->*m*->*p*-. The hydrocarbons were purified and supplied by A.P.I. Research Projects 6 and 44 respectively as part of the A.P.I.–N.B.S. research on pure hydrocarbons. W. H. A.

1090. Reaction of methyl radicals with *n*-butane. R. Gomer. *J. Amer. chem. Soc.*, 1950, **73** (1), 201–3.—The reaction of methyl radicals, produced by the photolysis of mercury dimethyl with *n*-butane has been studied and the activation energy calculated.
W. H. A.

1091. Pyrophoric lead as an ester interchange catalyst. C. S. Marvel and J. H. Johnson. *J. Amer. chem. Soc.*, 1950, **72** (1), 624.—Replacement of the litharge catalyst by pyrophoric lead in the preparation of polytetramethylene sebacate from butane 1,-4-, diol, and dimethyl sebacate yields a better grade of polyester. W. H. A.

1092. Co-polymerization by non-radical mechanisms. C. Walling, E. R. Briggs, W. Cummings, and F. R. Mayo. *J. Amer. chem. Soc.*, 1950, **72**, 48–51.—Results are given on copolymer compositions obtained in the non-radical copolymerization of styrene with acrylonitrile and with other monomers, and the effects of structure on reactivity in ionic polymerizations are considered. W. H. A.

1093. Studies on dry and oily friction. F. Morel and J. J. Trillat. *Rev. Inst. franç. Pétrole*, 1950, **5**, 33–8.—Details are given of two friction machines, for measurement of coeff of friction and of bearing friction. The first can operate up to 50 kg/cm² and at speeds of 0·5 mm–1·5m/sec; the pressure exertable in the second can attain 500 kg. Tests with graphite showed that friction coeff is largely influenced by max loading previously applied, during film formation. Graphite applied as flake is, however, only a suitable lubricant for low speeds, at speeds > a few cm/sec seizure occurs; a lubricating surface such as that given by colloidal graphite in oil suspension is not formed. Tests on a pure white oil containing varying amounts of stearic acid showed friction coeff to be independent of load, to vary with time, increasing in the case of pure oil and decreasing when oil contains 0·1% min of stearic acid. Coeff decreases with increasing speed, such change being less marked for oils containing more stearic acid. Increase of temp raises the coeff for neutral oil, but (up to 60° C) lowers it in the case of oils containing acid. Tests with a nickel-plated surface showed that friction coeff was, in this case, not influenced by addition of acid; as nickel is not readily attacked by fatty acids this confirms view that soap formation is essential for addition of acid to cause decrease in friction coeff. V. B.

1094. Surface tension of oils. A. Halpern. *J. phys. & colloid Chem.*, 1949, **53** (6), 895–7.—The surface tension of nine fixed oils including a liquid petroleum was determined by means of the capillary rise and the drop-wt methods over the temp range 20–130° C. D. F. J.

1095. Suspensibility of carbon black in detergent solutions. R. D. Vold and C. C. Konecny. *J. phys. & colloid Chem.*, 1949, **53** (8), 1262–79.—Experiments have been undertaken to determine the suspensibility of two carbon blacks in various aqueous solutions of detergents. There appears to be no direct relation between the critical miscelle concn and the concn of detergent at the max in the suspension isotherms. The mechanism of suspension, deduced from the experiments and confined by the

electron microscope, is deflocculation of the coarse aggregates of solid. This seems to be effected primarily by the zeta potential induced on the powder. Consideration must therefore be given to the chemical nature of both powder and detergent.

Evidence is also presented which indicates that the ability of a solution to suspend powders is not a satisfactory measure of its potential detergent power. D. F. J.

1096. Flame spectra. A. G. Gaydon. *Nature*, 1950, **165**, 170–3.—A review of combustion processes with emphasis on band spectra and theories of combustion which can be derived from their study.

All flames of hydrocarbons with air or O_2 show bands of C_2, CH, and OH. However, in flames at atm pressure the reaction zone is only *ca* 0·02 mm thick, and its structure cannot be studied in detail. At low pressure the thickness is increased, and it is possible to obtain flat, disc-shaped flames. Under these conditions CH bands predominate at the top and C_2 bands extend towards the base of the flame. Each band consists of a number of individual lines, and by measuring the intensity of a line the effective rotational temperature T, corresponding to the flame temp, can be calc. In C_2H_2 flames T varies from 5400° to 8750° K between 760 and 1·5 mm pressure. Measurements of translational and vibrational temp have also been made, but with less success.

Studies of band spectra also indicate that the formation of C_2 and CH in premixed flames requires polymerization of the hydrocarbon.

In addition to band spectra, continuous emission is always present, indicating processes of association and dissociation of molecules and the formation of ions. A yellow–green colour is due to the reaction $NO + O = NO_2$, and may be made the basis of a test for the presence of atomic O. If NO is added to the fuel in a hydrocarbon flame a yellow–green colour can be seen in the outer cone where CO and H_2 are burning, but not in the inner cone, where initial decomposition of the hydrocarbon occurs. Hence very little atomic O is present in the early stages of reaction. H. C. E.

1097. Ionization of paraffin wax by beta radiation. A. Gemant. *J. appl. Phys.*, 1949, **20** (10), 887–91.—A study is made of the primary ionization of paraffin wax by β-radiation from uranium and from carbon 14, using a conductivity method. Only small primary ions of relatively long mean life are detected by this method. Evaluation is made of the ionic mobility in paraffin and of the efficiency of ion-pair production. A comparison is drawn with the mobility in hydrocarbon oils. The level of the conductivities is lowered by the addition of polar compounds. No ionization was detected in the hydrocarbon polymers polystyrene and tetrafluoroethylene. D. F. J.

1098. Half life of C^{14}. R. C. Hawkins, R. F. Hunter, W. B. Mann, and W. H. Stevens. *Canad. J. Res.*, 1949, **27B** (6), 545–54.—Compensated gas counters of known efficiency, filled with carbon disulphide and carbon dioxide containing a mass-spectrometrically determined proportion of $C^{14}O_2$, have been used to determine the half-life of C^{14}. This was found to be 6360 ± 200 years. (Authors' Abstract.) D. F. J.

Analysis and Testing.

1099. Second annual reviews of analytical chemistry. Anon. *Anal. Chem.*, 1950, **22**, 2–135.—This review gives the latest theoretical developments which have taken place in the field of analysis during the year 1949. J. S.

1100. Repeatability of test results. E. D. van Rest. *Nature*, 1950, **165**, 230.—Summary of a meeting of the Royal Statistical Society's Industrial Applications Section at which five papers were presented.

The terms " repeatability " and " reproducibility " were criticized on the grounds of confusion, and entirely new names would be preferred to the practice of attaching new meanings to existing words. It was pointed out that whilst the two kinds of variability must be distinguished, the method of test cannot be said to be good unless the two are equal. Also, good replication cannot be taken to indicate the correctness of a result.

Difficulties in sampling were discussed, and it was shown that some existing methods of sampling can lead to batches being accepted which are actually outside specification

limits. In estimating errors it was emphasized that care is needed for overcoming the tendency for operators to take especial care during a previously arranged test.

The question of errors in routine analysis was discussed. In certain cases the tolerable limits for the result of a test can be estimated, and the experimental method can then be relaxed so that the test can be made much quicker without sacrificing the needed accuracy. This process is the equivalent of the engineer's " go or not go " gauge. H. C. E.

1101. An improved apparatus for obtaining boiling points of liquid mixtures. L. P. Eblin. *Chemical Education*, Feb. 1950, **21** (2), 67.—Apparatus used for the study of min boiling mixtures has been modified in order to obtain a steady thermometer reading. The modified apparatus is shown and its operation described. A. S.

1102. Photoelectric " Calorimetry " with inexpensive equipment. H. A. Liebhafsky and E. H. Winslow. *Chemical Education*, Feb. 1950, **21** (2), 61.—The paper described simple, inexpensive apparatus for photoelectric " calorimetry." The equipment is a photo-electric photometer to measure the absorption of radiant energy in the visible region for the purpose of estimating the iron, the copper, and the chloride contents of water. The apparatus is shown in diagrammatic form, and the paper includes details and results of the determination of chloride, copper, and iron in water. A. S.

1103. Physico-chemical micromethods of test for petroleum products. H. Levin, A. B. Morrison, and C. R. Reed. *Anal. Chem.*, 1950, **22**, 188–91.—Micro-methods are described for pour point, titer, and vapour pressure, each of which employs less than 1% of the amount of sample used in conventional macro-methods. J. S.

1104. Modified molecular weight apparatus. R. Matheson. *Anal. Chem.*, 1950, **22**, 172–5.—The apparatus described is a re-design of the water-filled differential vapour-pressure thermometer of Menzies (*J. Amer. chem. Soc.*, 1921, **43**, 2309), used in conjunction with a specially designed ebulliometer, permitting the determination to be carried out on as little as 100 mg of the sample. The operation is simple enough to be carried out by non-technically trained personnel, and the time required for a test is of the order of 25 min. Using chloroform as a solvent practically all of the high-boiling types of materials encountered in petroleum research may be handled. The boiling point of the unknown must be at least 150° C higher than the boiling point of the solvent. Changes in barometric pressure during the test do not affect the result. The equipment is standardized by four pure compounds covering the range from 128 to 890 in mol. wt. By a short extrapolation molecular weights up to 1000 may be determined with an accuracy only slightly less than that obtained using the benzene cryoscopic method. J. S.

1105. Colorimetric determination of dilute solutions of long-chain alkyl sulphates. F. Karush and M. Sonenberg. *Anal. Chem.*, 1950, **22**, 175–7.—A simple colorimetric method has been developed for the determination of long-chain alkyl sulphates and solutions as dilute as 5×10^{-6} M can be analysed with an accuracy of about $\pm 2\%$. The method depends upon the formation of a complex between the detergent anion and the cationic dye *p*-rosaniline hydrochloride. This complex is extracted into a mixed organic solvent 50% chloroform and 50% ethyl acetate, and its spectral absorption is read with a Klett Summerson colorimeter against the reference tube filled with the solvent. After making the necessary corrections for the blank the amount of alkyl sulphate was read from the appropriate calibration curve. The molar sensitivity of the method increases from octyl to do-decyl sulphate because of increasing efficiency of extraction of the dye-detergent complex with increase in chain length. The molar ratio of dye to detergent in the extracted complex is 1. J. S.

1106. Determination of sealing strength of paraffin wax. C. S. Funk, H. D. Davies, J. E. Hanson, and J. R. Segesser. *Anal. Chem.*, 1950, **22**, 179–82.—The method described offers a means of evaluating the strength of seal of wax wrappers with an accuracy within 5%. In addition to evaluating straight paraffins the method has been used to compare the sealing ability of wax blends and to evaluate wax additives. J. S.

1107. Semi-microfractionation by means of spinner columns. A. V. Cruthirds, W. C. Jones, and W. D. Seyfried. *Oil Gas J.*, 16.2.50, **48** (41), 105.—A column for the laboratory evaluation of small quantities of liquid is described. It consists essentially of a vertical glass tube containing a suspended chromel band which may be rotated at high speed. The column is of Pyrex, with a loose-fitting aluminium shield, and a number of cylindrical stills wound with chromel wire accommodate various size samples. The column head is solenoid operated. A table shows comparative performance data on atmospheric spinner and packed columns. G. A. C.

1108. Significance of properties of petroleum products—VIII. Sulphur content. C. V. Hill. *I.P. Review*, 1950, **4**, 42.—Most crude oils contain a certain amount of sulphur in different states of combination. These compounds may confer undesirable properties upon the petroleum fractions either because of their inherent nature or because they are converted into corrosive acid products during the distillation process. Thus it is important to be able to detect and estimate sulphur in the various petroleum products. Each type of product is differently affected by the presence of sulphur compounds depending upon the uses to which the product is put. The nature and importance of, and the method of determining sulphur in gasoline, other spirits, kerosine, diesel fuel, heavy fuel, bitumen, and lubricating oil are described. R. H.

1109. Apparatus for the simultaneous investigation of the viscosity of hydrocarbon systems and the change in their phase composition under conditions existent in petroleum strata. V. M. Fokeev. *Izvest. Akad. Nauk S.S.S.R., Otdel. Tekh Nauk*, 1950, 101–7.—Apparatus is described which is a falling-sphere viscometer operating under pressure (see Abstract 320) whose construction has been so modified that it can also serve as an electrical condenser for the measurement of dielectric const. Quant of liq and gas required are small (approx 4 g of each) and tests with *n*-pentane show that condenser capacity varies linearly with degree of filling by liq and that there is a sharp drop in capacity (otherwise independent of temp in range 17–41° C) when the b.p. of *n*-pentane is reached, the value for the dielectric const falling from 1·87 at 36·6° to 1·00 at 37·9° C. By rotating the apparatus and using a special condenser within the viscometer tube, measurement of dielectric const for the gas (upper) and liq (lower) phases can be made separately. Results are given for the system *n*-pentane/methane in the pressure range 100–225 atm for temp of 20° and 60° C. Dielectric const of the liq phase decreases with increasing pressure, whilst that of the gas phase increases; the values for the two phases becoming equal at approx 200 atm, showing the formation of a critical phase under these conditions. V. B.

1110. A fully automatic weathering machine. V. Virtala. *Paint Technol.*, Feb. 1950, **15** (170), 55.—A fully automatic weathering machine has been developed at the State Institute for Technical Research, Helsinki. It has a large capacity, and is made to conform to the climatic conditions prevailing in Finland. The machine consists of a cylindrical part in front and a cabinet at the back. In the bottom of the cylinder are placed a water-pump, a warm-air fan, a warm-water heater, and a compressor for the refrigerator, in the top is the driving mechanism. The weathering chamber itself occupies the middle of the cylinder, and is divided into three main parts: the dry, the humid, and the frost units. During the dry phase samples are exposed to radiation from mercury lamps, a warm air current, and ozone. The wet stage in addition to containing a drizzle and heavy shower, also offered exposure to ozone and mercury lamps. Detailed descriptions of the various parts of the machine and diagrams are presented, and the speed of operation is considered.

The machine has been used to test paints, lacquers, and roofing felts, and also to assess the merits of bitumen, tars and derivatives, metal coatings, weather-proofing and fire-proofing materials, new synthetics, etc. Estimates of durability are obtained. To obtain comparable results direct measurements of the mechanical properties of the samples are made before and after weathering. Results are similar to outdoor weathering. D. K.

Crude Oil.

1111. Analyses of crudes from Middle East, South America, Canada. Anon. *Oil Gas J.*, 2.3.50, **48** (43), 70.—The data is summarized from a report of investigations

recently published by the Bureau of Mines, U.S. Department of the Interior, and gives source of samples and some important characteristics of the crude oils, including total gasoline and naphtha, kerosine distillate, gas oil, light, medium, and heavy lubricating distillates.

The production of crude oil from the three areas is also shown for 1947–49 inclusive.

G. A. C.

Engine Fuels.

1112. National motor-gasoline survey. Summer 1949. O. C. Blade. *U.S. Bur. Min. Rep. Invest No.* 4644, Dec. 1949.—A.S.T.M. test results are given of the properties of regular and premium-grade gasolines sold in seventeen districts in the U.S.A. during the summer of 1949. The data covers gravity, distillation characteristics, Reid vapour pressure, contents of sulphur, gum and T.E.L., corrosiveness, and research and motor method octane values. Similar data for previous years are given for comparison. The trends indicated for the two grades are an increase of one or two octane numbers, the Reid vapour pressure remained nearly the same, the 10 and 50% evaporated temperatures had a downward trend of one degree, the 90% evaporated temperature showed the third successive and slight upward trend over those of preceding years.

W. H. C.

1113. Combustion of liquid fuels. D. B. Spalding. *Nature*, 1950, **165**, 160.—In this theory combustion is supposed to occur within a stagnant film surrounding the liquid mass. Chemical reaction occurs at a surface within this film and parallel to its boundaries. Fuel vapour and oxygen diffuse towards this surface from the interior and exterior respectively, and the combustion products diffuse outwards. A small fraction of the heat of combustion is conducted inwards to supply latent heat and enthalpy changes, and the remainder is conducted outwards. From this model the temperature and matter distributions can be calculated from the laws of thermal conduction and molecular diffusion, and the temperature of the reaction surface can also be found. If the film thickness is known the combustion rate can be calculated.

The theory has been confirmed experimentally by measuring the burning rate of kerosine from a spherical surface of 1½ in dia. The measured rates were about 50% of the theoretical, and the combustion rate increased: (1) as the heat of combustion, atmospheric temp and oxygen concentration increased; (2) as the latent heat of vaporization decreased. The volatility of the fuel has no effect when the steady state is attained.

H. C. E.

1114. Factors affecting octane number requirement. H. J. Gibson. *Refiner*, June 1949, **28** (6), 110–16.—Octane-number requirement for a car varies from time to time, and engines of the same make may vary as much as 20 O.N. in requirements. The variables affecting O.N. are discussed. Observations on several cars indicate that for practical purposes O.N.s of all engines are equally affected by barometric pressure—both quantities increase together. Changes in air humidity have widely different effects upon different engines. Average effect for seventy-two cars was 2·5 O.N. decrease for each 50 grains increase in humidity.

The effect of engine deposits is shown by results of "before-and-after-removal" tests on 162 cars. Average decrease in O.N. requirement was 9·4 O.N. Max decrease was 28·5 and min decrease was 0. Further tests on sixty-six cars in use on the roads showed that T.E.L. has little or no effect upon the change in O.N. requirements due to build-up or removal of engine deposits. Results are given on the effects of lubricating oils, base fuel composition, and type of driving, on the change in O.N. requirements due to deposits, but the results are inconclusive.

It is shown that the use of motor-car torque converters tends to change the pattern of knocking from knock at low speeds to knock at high speeds. Tests on two engines indicate that an increase of 80° F in cooling jacket temp corresponds to an increase in O.N. requirement of about 12 O.N. Tests on a hot-spot engine suggested that there is an optimum temperature for the hot-spot giving a min O.N. requirement.

The results are summarized showing the relative importance of the factors affecting O.N. requirement for normal operation of passenger cars. It is concluded that test-car data may be made more accurate and reproducible if test work is conducted under substantially constant atm temp, pressure, and humidity.

W. E. M.

1115. Oxidation, ignition, and detonation of fuel vapours and gases. X. Cause of preignition (surface ignition)—undoped liquid fuel. R. O. King and E. J. Durand. *Canad. J. Res.*, 1949, **27F** (9), 337–46.—The phenomenon of preignition is discussed, and C.F.R. engine experiments are described in which rich mixtures which oxidize readily to aldehyde are used. The occurrence of surface ignition depends upon surface and mixture temps. In temp conditions chosen to eliminate surface ignition, *n*-heptane can be used in the engine at a C.R. of 10 : 1, and the performance of acetaldehyde does not differ from that of a hydrocarbon fuel.

The theory is advanced that preignition (surface ignition), if occurring during compression, is due to partial oxidn of the fuel to aldehyde, small concns of this substance being sufficient to cause the hot surfaces in the combustion space to ignite the charge. The igniting effect may be early or late, *i.e.*, before or after spark ignition. Early surface ignition may cause destruction of pistons and exhaust valves of supercharged engines. This early surface ignition may occur in one cyl of a multi-cylinder supercharged engine because of uneven distribution of fuel. Continued running on the unaffected cyls may then prove disastrous. D. F. J.

1116. Oxidation, ignition, and detonations of fuel vapours and gases. XI. Loss of power coincident with the antiknock action of the carbonyls of iron and nickel in rich mixtures. R. O. King and E. J. Durand. *Canad. J. Res.*, 1949, **27F** (9), 347–58.—Experiments were carried out on a commercial gasoline doped with iron or nickel carbonyl using the C.F.R.–A.S.T.M. motor method of knock testing. The increase in usable C.R. obtained by the addition of these dopes is not accompanied by a commensurate increase in power. The % by which the observed power for the doped fuel is less than that obtainable if a non-knocking fuel were used at the same C.R. has been determined.

It is stated that the experiments of this part confirms the theory advanced in Part III (see Abst. No. 1689, 1948) that the metallic anti-knocks act by promoting the high-temp surface oxidn of hydrocarbon fuel to steam and CO_2, met by inhibiting a homogeneous reaction by breaking reaction chains. D. F. J.

1117. Oxidation, ignition, and detonation of fuel vapours and gases. XII. High compression ratio Otto cycle gas engine and the adverse effect of high jacket temperatures on thermal efficiency. R. O. King, E. J. Durand, and J. A. Morrison. *Canad. J. Res.*, 1949, **27F** (11), 435–49.—A series of C.F.R. engine trials were run using town gas as fuel at a C.R. of 10 : 1 and at jacket temps of 140, 212, 302, 351° F. The mixture strength at each jacket temp was varied from the weakest to the richest on which the engine would run steadily. It is shown that thermal eff decreases as the jacket temp is raised. The character of the results and previous experiments indicate that this decrease is due to the effect of flameless combustion, during compression, of hydrogen on oxide-coated surfaces to produce steam. The decrease in eff tends to be reduced by the decrease of heat loss during expansion and compression. The decrease of eff becomes greater as the mixture strength is increased, because the velocity of the surface reaction increases accordingly. The performance of the C.F.R. engine running on town gas at a C.R. of 10 : 1 is compared with that of a compression-ignition oil-engine running at a C.R. of 10 : 1. The C.F.R. engine was superior in respect of max power developed and range of quality control and not greatly inferior in respect of thermal eff. D. F. J.

1118. Patent. D. R. Stevens, assr to Gulf Research and Development Co. U.S.P. 2,495,555. 24.1.50. Improved diesel fuel made by adding to a hydrocarbon diesel a minor proportion of a sulphurized cracked petroleum distillate to improve ignition quality. C. F. S.

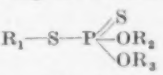
Lubricants.

1119. Lubricating oil additives. V. A. Kalichevsky. *Refiner*, June 1949, **28** (6), 97–102.—Following a general discussion on the use of lube additives, a series of tables is presented classifying the various types of additive and giving patent numbers. W. E. M.

1120. Lubricating oil additives. E. Kadmer. *Erdöl u. Kohle*, 1950, **3**, 73–7.—A review of the nature and function of additives of the following types: oxidn inhibitors; heavy-duty agents; extreme-pressure agents; V.I. and pour-point improvers; anti-foaming agents. Most of the information quoted is from U.S. sources, but brief particulars are given of some German (I.G.) oxidn inhibitors. Attention is paid to the exact German translation of English additive terminology. V. B.

1121. Magnitude of the mechanical component of solid friction. C. D. Strang and C. R. Lewis. *J. appl. Phys.*, 1949, **20** (2), 1164–7.—An experiment is described in which the magnitude of that portion of dry, kinetic friction which is contributed by Coulomb friction, or the mechanical interlocking of surface irregularities, is measured. The results indicate that the work of the mechanical component of friction accounts for only a few per cent of the work of total measured friction. There is a possibility, however, that smaller surface irregularities, which could not be detected, would increase the mechanical component of friction. It is shown that the coeff of dry kinetic friction is essentially independent of the surface roughnesses that constitute the ordinary engineering surface finish. D. F. J.

1122. Patents. E. B. Cyphers, assr to Standard Oil Development Co. U.S.P. 2,494,332, 10.1.50. An extreme pressure lubricant made up of a petroleum-base oil containing 1–20% of a material having the formula :—



R_1 being halogenated rosin ester, R_2 and R_3 aliphatic groups of 2–10 carbon atoms each.

E. Lieber, assr to Standard Oil Development Co. U.S.P. 2,494,341, 10.1.50. Describes a lubricant comprising a waxy mineral lubricating oil, 0·5–5 mols of an alkyl mercaptan having from 1–20 carbon atoms, and 1 mol of an aromatic compound having less than 20 carbon atoms.

J. W. Starrett, assr to Standard Oil Co. Indiana. U.S.P. 2,495,030, 17.1.50. A flushing oil consisting of a catalytic-reformed naphtha fraction, mono- and poly-methylated aromatic hydrocarbons, 1–20% of a phosphorus- and sulphur-containing reaction product of an olefin polymer, and a phosphorus sulphide.

H. E. Redman, assr to Socony-Vacuum Oil Co. U.S.P. 2,495,478, 24.1.50. A mineral-oil composition containing 0·1–10% of an oil-soluble, metal salt of an acidic phosphorous and sulphur containing reaction product.

R. A. Butcosk, assr to Socony-Vacuum Oil Co. Inc. U.S.P. 2,495,651, 24.1.50. A high-temperature, ball-bearing grease comprising mineral lubricating oil, and 15–30% of alkali-metal soap of a fatty acid, saponifying, and polymerizing the fatty-acid component. C. F. S.

Special Hydrocarbon Products.

1123. Physical and technical properties of hydrocarbon waxes and their classification and nomenclature. K. H. Grodde. *Erdöl u. Kohle*, 1950, **3**, 61–72.—Twenty-five equations are given relating the physical properties mol. wt., set. pt., d, n_D, visc, and b.p.) of n paraffins which are solid at room temp., d, n_D, and visc are measured at 100° C. Limits of accuracy for the calculation of the various characteristics are indicated. Application of similar formulæ to *iso*- and ring-paraffins is discussed, and expressions are derived for an "asymmetry value" and a "ring value," based on lowering of set. pt. and increase in d respectively, in conjunction with the mol. wt. Both these values are of similar magnitude, and their sum (S) can be determined from the set. pt. and either d or n_D, without a knowledge of the mol. wt., according to the expressions $S = 10^3 . d - 709 - 0{\cdot}75$ (set. pt.) or $S = 2{\cdot}10^3 . (n - 1{\cdot}396) - 0{\cdot}84$ (set. pt.). Physical properties of wax mixtures are considered, with particular reference to set. pt. The following formula for calculating the set. pt. of a binary mixture has wide applicability and can, by successive steps, be applied to mixtures containing more than two components :—

$$A - B = (155 - A)\frac{0{\cdot}30 + 35 . c . (1 - c)}{100 . c . (1 + c)}$$

where A = set. pt. of the higher-melting component, B = set. pt. of mixture, and c = concn of higher-melting component. A " heterogeneity index " is derived which can be calc from a fractional crystallization of the wax (using dichlorethane) and which denotes the width of the set.-pt. range of the sum of the component fractions; the influence of this characteristic on flow properties is considered. Solvent retention in wax pastes depends upon the proportion present of wax of high retentivity, a property particularly evident in ceresin. Examination of the oxidn sensitivity of paraffins showed fatty acids from *iso*-paraffins to be of higher mol. wt. than those from *n*-paraffins. Ceresin is very oxidn resistant. Solvent de-oiling of waxes is considered and dichlorethane found to be the most suitable solvent since it separates waxes on the basis of set. pt. independently of mol. wt.; single-stage de-oiling using high solvent ratios is preferable to multi-stage operation, but the converse applies to dewaxing of oil. In refining waxes 120° C is optimum temp for earth treatment and 160–220° C for H_2SO_4 refining, the latter temp rising with increasing " asymmetry value." A laboratory refining procedure is described. Classification of waxes is according to three main characteristics, based on the physical properties considered; the " ceresin character " (X) which is denoted by

$$X = \frac{S}{100 - \text{set. pt.}}$$

where S has the significance previously mentioned. This characteristic ranges from $X<0{\cdot}1$ for paraffins to $X>1{\cdot}25$ for special grades of ceresin. Division according to set. pt. is made into five groups (35–50°, 50–65°, 65–80°, 80–95°, and >95° C) and according to oil content into four groups (<1, 1–10, 10–25, and 25–75%). V. B.

1124. Synthetic waxes. L. Ivanovszky. *Chim. et Ind.*, 1950, **63**, 239–45.—Definition of waxes as fatty acid esters cannot now be considered correct, and a suitable modern definition should be based on physical properties rather than chemical. A proposed definition describes waxes as thermoplastic org substances, usually melting at 50–90° C to liquids of low visc, forming pastes and possessing a permanent lustre. Various types of waxes are discussed; only three completely synthetic processes of wax manufacture exist, viz., hydrogenation of carbon monoxide, low-temp coal hydrogenation, and ethylene polymerization. All other " synthetic " waxes include a measure of naturally occurring material. Charts show derivation of I.G. waxes from lignite, and a table gives a list of the main synthetic waxes, with an indication of their composition. V. B.

Coal, Shale, and Peat.

1125. Estimation of the hydrocarbons in primary tars by hot chromatography. M. Vahrman. *Nature*, 1950, **165**, 404.—When tars derived from Colonial coals were percolated at *ca* 100° C through a silica-gel column, the bases and resinous compounds were adsorbed at the top, and the hydrocarbons at the bottom of the column. The hydrocarbons were eluted by hot, light petroleum (100–120°) in two fractions, of which the first contained saturated and the second partially unsaturated ring compounds. The hydrocarbons were recovered by distilling off the petroleum under reduced pressure. H. C. E.

Miscellaneous Products.

1126. Toxicity of solvents. 2. A. J. Amor. *Paint Mnfr*, Mar. 1950, **20** (3), 89.—The following groups of solvents are considered with reference to their possible toxicity: glycols, halogenated compounds, hydrocarbons, ketones, nitriles, nitro-hydrocarbons, and sulphur derivatives.

A few members of each group are discussed in some detail. All members of the hydrocarbon group possess the common property of producing narcosis of anæsthesia if inhaled in sufficient quantity. The physiological effects of benzene, toluene, petroleum spirit, benzine, and white spirit are particularly noted.

A table showing gassing accidents due to solvents reported to Factory Department of the Ministry of Labour during 1939–48 and tabulated data of toxic effects of individual members of the group are presented. D. K.

1127. Patent. J. D. Danforth, assr to Universal Oil Products Co. U.S.P. 2,495,890, 31.1.50. Resinous condensation products from an aldehyde or a ketone and a *n*-alkenylarylamine. C. F. S.

Engines and Automotive Equipment.

1128. The Steyr diesel. Anon. *Auto. Engr*, Mar. 1950, **40** (525), 109.—The Steyr W.D. 413 engine is so designed that each cylinder constitutes a complete unit consisting of cylinder-head, piston, connecting-rod, liner, valves, and rocker gear. The complete range of engines comprises one- and two-cyl units with composite self-supporting grey-cast-iron crankcases, which are suitable for tractors or stationary applications, and four- and six-cyl engines of light-alloy construction designed for commercial vehicles and motor buses. The four- and six-cyl engines of fundamentally similar design but with a modified cylinder-head and piston are employed as petrol engines for commercial vehicles. All Steyr engines of type W.D. employ a special combustion system with subdivided combustion chamber called the Steyr Crossflow Swirlchamber. Very intimate mixing of fuel and air is achieved giving high combustion efficiency. Further details of combustion chamber, five-bearing crankshaft, and valve mechanism are included in the paper. A. S.

1129. Diesel engine crankcase safety precautions. C. C. Pounder. *Motor Ship*, Mar. 1950, **30** (362), 489.—Six examples are given of crankcase explosions and recommendations made for practicable safety precautions. I. G. B.

1130. New G.M. Diesel-electric locomotive. Anon. *Gas Oil Pwr*, 1950, **45**, 16.—The power unit of this locomotive is a two-stroke uniflow scavenging engine. The cylinders, of 8·5-in bore and 10-in stroke, are arranged in two banks to form a 45° Vee. Cooling is accomplished by water and forced air circulation. The lubricating system employs a gear-type pump for the pressure-lubricating points, whilst another pump supplies oil for piston cooling.

The 1200-, 1500-, and 2250-b.h.p. locomotives are powered by twelve-cyl, sixteen-cyl, and two twelve-cyl units respectively, and the outputs are fed to 600 V D.C. generators. H. C. E.

1131. A.E.C. underfloor-engined vehicle. Anon. *Gas Oil Pwr*, 1950, **45**, 28.—Designed for installation under buses, this six-cyl engine has bore and stroke of 120 and 142 mm, with an output of 125 b.h.p. at 1800 r.p.m. The compression ratio is 16 : 1. Dry-sump lubrication is used with pressure lubrication to all main and big-end bearings, and low-pressure lubrication to the camshaft and valve gear. Details of the engine construction are given. The fuel-injection equipment is of the pilot-injection type, and the injectors are so mounted that each is immediately accessible. Incorporated devices ensure that the engine can be removed from the vehicle by two men in less than 15 min. H. C. E.

1132. Experimental coal-burning gas turbine. Anon. *Gas Oil Pwr*, 1950, **45**, 6.—The fuel used in this experimental turbine is pulverized coal, fed continuously to a combustion chamber and burned under 60 p.s.i. pressure. A combustion efficiency greater than 90% is obtained. The turbine is driven by superheated air, operates without smoke, and requires a min of lubrication. After 38 hr the components were all in excellent condition. H. C. E.

1133. [Ruston and Hornsby] gas turbine. Anon. *Gas Oil Pwr*, 1950, **45**, 10–14.—This gas-turbine generating-set developing 750 kW has been installed permanently in the firm's power-station. Details of the lay-out and construction are given.

Incoming air is compressed by a thirteen-stage, axial compressor and raised to 420° C in a heat exchanger. In the combustion chamber the hot air is mixed with gas oil, and initial ignition is accomplished by a high-energy spark. The combustion products then pass through the compressor turbine and the power turbine in turn. Provision is made for cooling the blades of both turbines by means of air supplied

through the rotor shaft. The alternator is driven through a double-helical, epicyclic reduction gear which reduces the shaft speed from 6000 to 1500 r.p.m.

On test the fuel consumption at half and full were 0·77 and 0·59 lb per b.h.p/hr. respectively, and the lub. oil consumption was negligible. H. C. E.

1134. Switzerland's new 20,000 kW gas turbine. Anon. *Gas Oil Pwr*, 1950, **45**, 14–15.—The gas turbine operates on the Sulzer high-pressure cycle, consisting of three sets of turbo machines: the feed set (gas-turbine with compressor drawing atmospheric air); the circuit set (air-turbine with medium- and high-pressure compressors); and the output set (gas-turbine with generator). The plant is designed for a max gas temp of 650° C, giving an efficiency of 35% at full load. Variations in output are effected by changing the pressures in the circuit and keeping the temp of the combustion chambers constant.

High-visc fuel oil is heated to 100° C before burning, and 45 cu. m/sec of air are used. H. C. E.

1135. Fuel injection tests. Anon. *Auto. Engr*, Mar. 1950, **40** (525), 93.—The paper describes the fuel-injection test equipment developed by Leslie Hartridge Ltd. for service testing and for use by manufacturers of fuel-injection equipment. The equipment was originally developed for the purpose of making periodic checks so that any fall-off in performance could be detected before engine performance and fuel consumption were adversely affected. Details are given of the apparatus used and the tests carried out on nozzles and fuel-pumps. Discussed separately are manually operated and automatically controlled nozzle testers. A. S.

1136. Bristol Cavalcade. Anon. *Flight*, 16.2.50, **57** (2147), 213.—The journal contains a special issue of aircraft, engine, and armament development over forty years at the Bristol Co. I. G. B.

1137. Patents. P. Mongitore, assr to Fiat S.p.A. U.S.P. 2,494,102, 10.1.50. The method of running-in internal-combustion engines by connecting the inlet manifold with the exhaust manifold thereby permitting the circulation of an inert gaseous fluid in the circuit made.

P. A. Jennings, assr to Armco Steel Corpn. U.S.P. 2,495,731, 31.1.50. Stainless steel resistant to leaded fuels at high temperatures containing about 0·40–1·50% carbon, about 12–35% chromium, about 2–35% nickel, about 3–12% manganese, silicon not exceeding about 0·25%, and the remainder substantially all iron.

A Starts, assr to Duncan Parking Meter Corpn. U.S.P. 2,495,784, 31.1.50. A valve control for crankcase-compression engines.

D. M. Lawrence, assr to Bendix Aviation Corpn. U.S.P. 2,495,976, 31.1.50. Lubricant metering system.

P. A. Jennings, assr to Armco Steel Corpn. U.S.P. 2,496,247, 31.1.50. Stainless steel resistant to corrosion by leaded fuels at high temperatures, containing about 0·08–1·5% carbon, about 12–30% chromium, about 4–17% manganese, silicon not exceeding 0·25%, about 0·04–0·15% sulphur, phosphorous not exceeding about 0·04%, remainder substantially all iron.

P. A. Jennings, assr to Armco Steel Corpn. U.S.P. 2,496,248, 31.1.50. An internal-combustion-engine valve of stainless steel resistant to corrosion by leaded fuels at high temperatures, containing about 0·35–1·0% carbon, about 15–30% chromium, about 4·5–20% nickel, about 1–4·5% molybdenum, silicon not exceeding about 0·15%, remainder substantially all iron. C. F. S.

MISCELLANEOUS.

1138. Natural gas . . . problem or panacea? J. B. Wells. *Fuel Oil and Heat*, Feb. 1950, **9** (2), 35.—The expansion of the use of natural gas as fuel in the Middle Atlantic and New England states is considered. A question of national economic policy arises, whether the advantages of natural gas to a few promoters should over-

shadow the economics of the basic industry of petroleum production, refining, and marketing with its great capital interest and innumerable employed workers and small business men and its dependable organized and functioning procedure.

Troubles arising from failure of the natural-gas pipeline due to sabotage, bombing, or an act of Nature and the subsequent cutting off of supply are compared with those arising in similar circumstances in the present distributive system.

The impact of the substitution of natural gas for petroleum on the transportation industry, and the motives of the promoters of the scheme are also investigated.

D. K.

1139. Some impressions of the paint industry of the U.S.A. H. W. Rudd. *Paint Mnfr*, Mar. 1950, **20**, (3), 81.—The organization of the paint industry in the U.S.A., the link-up between research institutions and the paint manufacturers and users, methods of production and testing, and the requirements of the public are discussed. The differences in English and American paint practice are stressed.

Much interest is being taken in vinyl coatings in the U.S.A. It was noted that there was a diversion of opinion between aluminium and chalking white finishes for tank painting. The use of cathodic protection for tanks is discussed. D. K.

1140. Guide for making cost estimates for chemical-type operations. C. W. Van Noy, T. C. Dunville, R. G. Dressler, and C. C. Chaffee. *U.S. Bur. Min. Rep. Invest No.* 4534, Nov. 1949.—The procedure outlined in this report is intended for the use of engineers, estimators, and accountants engaged in estimating the cost of chemical-type operations such as the production of the synthetic liquid fuels, anhydrous ammonia, etc. It is concerned with operating costs only, as investment costs have been considered in numerous other publications. This report has been prepared to assist in making of cost estimates for the following purposes :—

(1) To make an economic study of the operations of plants and equipment of new design.

(2) To make economic studies of new products and methods of producing them.

(3) To include all elements of cost, such as direct costs, indirect costs or burden, fixed costs, etc.

(4) To present the various cost elements, so arranged that they may be compared with other cost estimates of like or similar nature.

Types of operation are discussed and basic factors described. Schedules, indicating the data required for the numerous headings and showing the depreciation rates to be applied for the various components, are given. W. H. C.

1141. Effect of plant process size on capital cost. P. W. Sherwood. *Oil Gas J.*, 9.3.50, **48** (44), 81.—First costs of process plants and units are shown to follow the equation (Cost of plant of capacity A) = (Cost of plant of capacity B) $(A/B)^x$, where x varies between 0·58 and 0·82 and has an average value of 0·7. Occasional exceptions to this rule are noted, especially for high-pressure units and for very small plants, for both of which the exponential factor is considerably lower.

Nineteen types of plant and units are listed, and exponent values applying to the process units are given.

Two figures display cost data plotted for various types of plants listed.

G. A. C.

1142. Division, nomenclature and classification of petroleum products and especially lubricating oils. C. Zerbe. *Erdöl u. Kohle*, 1950, **3**, 85–8.—Details are given of the classification of pet products according to German standards (DIN), the pre-war German customs classification and the proposed European customs system, the latter in some detail. Schwarz's table (1930) giving names for ten main products in eighteen countries is reproduced. Lub-oil classification is discussed, and a table given in which for an oil of visc (50° C) = 10° E, limits of d_{20}, V.I., visc pole ht, C.R. (Con), an. pt., and H_2 content are suggested for four different bases (aromatic, naphthenic, paraffinic, and synthetic (paraffinic)). Lub.-oil classification according to use and characteristics (DIN 6579) and production (DIN 6530) is also given. V. B.

1143. A discussion on the physics and chemistry of hydrocarbon gels. *Proc. Roy. Soc.* A, 6.1.50, **200** (1061), 136–91. (*Royal Society Meeting, London, March* 24, 1949.)—At this discussion, after the opening remarks by the leader of the discussion, E. K. Rideal, the following papers by various authors were presented :—

Gelation of aluminium soaps in hydrocarbons.
Factors which affect the gelling characteristics of aluminium soaps.
The swelling and solubility of cellulose acetate in benzene/xylenol mixtures.
Aluminium soaps, their nature and gelling properties.
Some flow properties of concentrated high-polymer solutions.
The equilibrium swelling of cross-linked amorphous polymers.
Rheology of hydrocarbon gels. (Summary.)
Thermodynamics and rheological behaviour of elasto-viscous systems under stress. (Summary.)
The rheology of " elastic " non-Newtonian fluids. W. H. C.

1144. Role of metallic soaps in film formation. R. F. Bowles. *J. Oil Col. Chem. Assoc.*, 1950, **33**, 97.—Experiments were carried out involving flocculation, evaporation, and oxidation/polymerization phenomena. Materials used were : neutral naphthenates, a linseed stand oil of 80 poises viscosity at 25° C and an aliphatic mineral oil viscosity 50 poises at 25° C, where pigmentation was involved pure anatase titanium dioxide was used. Results indicate that the soaps are strongly and rapidly adsorbed at all interfaces. The adsorbed layers are thin, probably monolayers. Naphththenic acid itself and most of the naphthenates strongly deflocculate the TiO_2/mineral-oil dispersion.

There is some evidence that zinc, lead, and calcium assist film formation by promoting flocculation and that the use of soaps of these metals as " driers " is for this purpose.

From the results obtained it appears that neutral metallic soaps, in the sort of film with which the surface-coating industries are concerned, are likely to function as powerful surface-active materials with a general tendency to act as flocculating agents in all cases where more than one phase is present.

Several graphs and tables are included. There are six literature references.

D. K.

1145. Scouring of wool with synthetic detergents. J. A. Hepworth. *J. Soc. Dyers Colourists*, 1950, **66** (2), 101.—The main types of synthetic detergent available in the U.K. and the U.S.A. are described. They represent 7–10% of the detergents sold in this country and about 25% for the U.S.A. The speed of introduction of these products has been closely connected with the development of the production of chemicals from petroleum, and the availability of the necessary long-chain olefins.

Recent progress in scouring raw wool with synthetic detergents is reviewed, topics discussed including variations in raw wool and scouring plants, the effects of electrolytes, soda ash and the detergents themselves, scouring temps, bulk-working recommendations, starting concentrations, etc. It is concluded that the new products present new possibilities in the industry. One or two problems connected with the use of synthetic detergents remain to be solved, but the fundamental fact that it is possible to scour any type of raw wool clean and to grease contents required by the trade, at a reasonable cost, has been established. No comments are made on the influence of physical properties, since this problem is at present under investigation. C. N. T.

1146. Cooling water slime. R. B. Wise. *Oil Gas J.*, 23.2.50, **48** (42), 170.—The three main groups of organisms which may give trouble in re-circulating-water systems are algæ, bacteria, and fungi.

The subdivisions of each of these three main groups, the occurrence and action of each division, and the trouble-making organisms are discussed.

The correct interpretation of microbiological analyses is essential in order to prescribe the treatment for greatest effectiveness.

The application of chemicals to control slime is briefly dealt with. G. A. C.

1147. Acid sludge fuels used in steam generation. H. Kaye and R. K. Spencer. *Oil Gas J.*, 9.2.50, **48** (40), 80.—A general discussion on acid sludges is given, with an

account of methods of disposal including production of sulphuric acid and use as fuel for steam generation.

Method of disposal of about 10,000 tons per annum of mixed acid sludge from treatment of lubricating oils, technical white oils, and liquid paraffin at Manchester oil refinery, England, by burning, is outlined.

The burning arrangement consists of a rectangular firebrick, Dutch-oven-like structure. One burner is used for furnace, the sludge being atomized by steam.

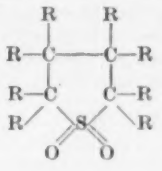
The thermal efficiency of the boiler is 55%, and cost of maintenance of whole unit is around 85 pence per ton. G. A. C.

1148. Storage batteries. J. E. Cassidy. *Chem. Education*, Feb. 1950, **21** (2), 63.—Text-books invariably contain very little information regarding the lead storage cell, the Edison cell, and the nickel–cadmium cell in spite of the fact that these three cells are the only ones of practical use as storage batteries. The paper contains information about these three commercial batteries and compares their respective features. A. S.

1149. Patents. L. J. Jubanowsky, assr to The Baker Castor Oil Co. U.S.P. 2,494,559 17.1.50. A coating and impregnating composition which is resistant to the solvent action of hydrocarbons.

H. J. Oberding, assr to Universal Oil Products Co. U.S.P. 2,494,628, 17.1.50. An electric moisture–temperature device for measuring the temperature at which a hydroscopic material reaches a water content equal to that of the gaseous medium contacting the material.

R. C. Morris and J. L. Van Winkle, assrs to S.O.D. Co. U.S.P. 2,495,467, 24.1.50. Thioethers of polyalkylated cyclic sulphones-compounds having the structural formula :



C. F. S.

BOOK REVIEW.

Boron Trifluoride and its Derivatives. H. S. Booth and D. R. Martin. New York: John Wiley & Sons, Inc., London: Chapman & Hall Ltd., 1949. Pp. ix + 315. 40*s*.

This is a book for reference rather than for reading as a text-book. It is an ordered and organized presentation of facts and experimental observations together with a considerably smaller proportion of theoretical interpretation and discussion. Its value as a work of reference is enhanced by a bibliography of over a thousand items, author index, subject index, and formulæ index, which together occupy one-fifth of the book. The bibliography ranges from Davy's papers in 1908 up to the end of 1947: but the authors lay no claim to absolute completeness. As they say in their preface "articles containing information on boron trifluoride have rarely been indexed whenever boron trifluoride has been used as an agent."

The chapter headings are: "History and preparation"; "Physical properties"; "Chemical properties"; "Co-ordinating power"; "Fluoboric acids and their salts": "Boron trifluoride and its derivatives as catalysts"; "Analysis"; and "Practical handling."

The pivotal chapter as far as workers in the petroleum industry are concerned is, no doubt, Chapter Six. This opens with four pages of theoretical considerations, followed by nearly sixty pages of reports and synthesis, polymerizations, isomerizations, and degradations catalysed by boron trifluoride and its derivatives, and ends with a short note on the recovery of the catalysts.

Underlying the fascinating chemistry of boron trifluoride and its use as a catalyst is the strong electron-accepting character of the molecule, with its small central atom with only six electrons in its outer shell. This point is well brought out throughout the book.

The general standard of production of the book is as high as one would expect. But if one might note a minor blemish, the arrows denoting co-ordinate links in structural formulæ are frequently not only identical with those indicating a reaction, but are also as generously spaced from the groups they are intended to connect as are the arrows indicating reactions from the different formulæ in a synthesis; with the result that it is sometimes not immediately clear what is meant. C. R. P.

BOOKS RECEIVED.

East Indies Episode. Johan Fabricius. London: The Shell Petroleum Co. Ltd., 1949. Pp. 142 + ix.

An epic of the destruction of the oilfields and refineries in the East Indies in order to deny them to the enemy when the Japanese overran the area. It is based on reports written, or stories told, by employees of the B.P.M. and associated companies. In a foreword Mr B. Th. W. van Hassalt, managing director of the B.P.M., records that 317 of the staff of 1506 at the time of the invasion were killed in action or died during, or as a result of, internment.

The volume is number three in the "Shell War Achievements" series.

The Engineers. Harold Nockolds. London: The Shell Petroleum Co. Ltd., 1949. 1949. Pp. 108 + xi.

This fourth volume in the series on "Shell War Achievements" records the part played by the engineers of the oil industry during the war. It recalls events and accomplishments in all parts of the world and in all spheres of activity.

Bibliography on Offshore Petroleum Developments. Emory N. Kemler. Houston, Texas: Southwest Research Institute, 1949. Pp. 16.

A bibliography of 409 references to the literature available on deep-water operations and equipment covering the Gulf of Mexico, Lake Maracaibo, off the California Coast, and other areas. This is the first publication of the Division of Oceanography and Meteorology.

Summary of Papers and Patents Published 1947–1948 of Interest to the Benzole Industry. London: National Benzole Association, 1949. Pp. 133.

Over 800 papers and patents are collated and summarized in this volume, which follows the general lines of its predecessors, except that the sub-section on production of motor spirit from water gas has been omitted.

1949 Book of A.S.T.M. Standards Including Tentatives. Part 2: Non-ferrous metals. Pp. xxvi + 1140. **Part 4: Paint, Naval stores, wood, adhesives, paper, shipping containers.** Pp. xxx + 1289. **Part 5: Textiles, soaps, fuels, petroleum, aromatic hydrocarbons, water.** Pp. xxxi + 1697. Philadelphia: The Society.

The previous edition of this triennial publication was issued in five parts. With the extension of the Society's work into new fields, the 1949 edition comprises some 8300 pages, and for convenience it was decided to issue the publication in six parts. In part 5 the section on Petroleum Products and Lubricants covers Motor and Aviation Fuels; Diesel and Burner Fuels; Kerosine and Illuminating Oils; Lubricating Oils; Greases; Petrolatums and Paraffin Waxes; Plant-spray Oils and Petroleum Sulphonates; Electrical Insulating Oils; Light Hydrocarbons; Hydrocarbon Solvents; Crude Petroleum; Thermometers and Miscellaneous. Also included in Part 5 are Coal and Coke and Engine-test Methods for Rating Fuels.

B.S. 572 : 1950 Interchangeable conical ground glass joints. London: British Standards Institution, 1950. Pp. 12. 2*s*. net.

Covers three series of joints. Series B of a size useful in the construction of apparatus for general laboratory and distillation purposes; C, for stoppers on apparatus with comparatively narrow necks; D, for stoppers for such articles as weighing bottles.

B.S. 1627: 1950. Cold drawn low carbon steel tubes. London: British Standards Institution, 1950. Pp. 7. 2*s*. net.

Covers cold-drawn, seamless, low-carbon steel tubes for use in tubular heat-exchangers, condensers, and similar heat-transfer apparatus.

B.S. 1628 : 1950. Cold drawn seamless alloy steel tubes. London: British Standards Institution, 1950. Pp. 7. 2*s*. net.

Applies to cold-drawn, seamless tubes in two grades of alloy steel for use in tubular heat-exchangers, condensers, and similar heat-transfer apparatus.

B.S. 759 : 1950. Valves, gauges, and other safety fittings for land boiler installations. London: British Standards Institution, 1950. Pp. 23. 3*s*. net.

Deals with the materials and construction of valves, gauges, and other fittings.

B.S. 1123 : 1950. Valves, gauges, and other safety fittings for air receivers and compressed air installations. London: British Standards Institution, 1950. Pp. 9. 2*s*. net.

This revised standard supersedes B.S. 1123 : 1943, and provides for valves, gauges, and other safety fittings for air-receivers and compressed-air installations, for design pressures not exceeding 1000 p.s.i.

Wire Rope (export classification). U.S. Department of Commerce Commercial Standard CS154E-49. Washington, D.C.: U.S. Govt. Printing Office, 1949. Pp. 59. 15 cents.

This standard provides minimum requirements for wire rope manufactured in the U.S. Definitions and a glossary of terms are also given.

Consulting Engineers Year Book, 1950. London : Princes Press Ltd., 1950. Pp. 248. 20*s*.

Gives details of engineering institutions and societies, a " Who's who " of British and overseas consultants, a survey of 1949, and a directory of trademarks.

Institution of Mechanical Engineers Proceedings. Vol. 159. War emergency issues 37–46, 1948. London : The Institution. Pp. ix + 437.

Includes lectures on internal-combustion turbines given 3.11.48 and 4.11.48 : " Prospects of land and marine gas turbines," " Part-load performance of various gas turbine engine schemes," " Fuel problem in gas turbines," " Performance of axial flow turbines," " Heat flow in the gas turbine," and " Three-dimensional flow theories for axial compressors and turbines." Among other papers are " The development of variable specific heat charts and graphs, and their application to internal combustion motor problems," " The calculation of compressible fluid flow by the use of a generalized entrophy chart," " Chart for the investigation of thermodynamic cycles in internal combustion engines and turbines," " The design of contra-flow heat exchangers," and " Thermal analysis on contra-flow heat exchangers."

APPLICATIONS FOR MEMBERSHIP OR TRANSFER.

MAY 1950.

The following have applied for admission or transfer to the Institute. In accordance with the By-laws, the proposals will not be considered until the lapse of at least one month after the publication of this *Journal*, during which time any Fellow, Member, or Associate Member may communicate by letter to the Secretary, for the confidential information of the Council, any particulars he may possess respecting the qualifications of suitability of the candidate.

The object of this information is to assist the Council in grading the candidate according to the class of membership.

The names of candidates' proposers and seconders are given in parentheses.

Applications for Membership.

AFSHAR, M. V. G., assistant chemist, Anglo-Iranian Oil Co. Ltd. (*L. A. Wilshere; A. Aghdaey.*)

ANCELL, Harry, laboratory assistant, Manchester Oil Refinery Ltd. (*G. H. Harries; H. Kaye.*)

BEAN, John Gordon, works manager, Messrs. C. C. Wakefield & Co. Ltd. (*G. H. Thornley; J. C. Cragg.*)

BUGBEE, Herbert Lewis, assistant to Asst. General Sales Manager, Anglo-American Oil Co. Ltd. (*C. Chilvers; R. D. Streeton.*)

BULLICK, Eric Douglas, director, Messrs. Turtle & Aird Ltd. (*V. M. Farrant; P. C. Masters.*)

CAKE, Thomas William, deputy shift superintendent, Anglo-American Oil Co. Ltd. (*F. Mayo: A. W. Pearce.*)

FORSYTH, David Courtney, chemist, Shell Co. of New Zealand Ltd. (*T. T. N. Coleridge; S. H. Edwards.*)

GREGORY, Alan Stanley, laboratory assistant, "Shell" Refining & Marketing Co. Ltd. (*D. H. Japes; E. J. Labrum.*)

GRIFFITHS, Oswald Hardy, chief engineer, Iraq Petroleum Co. Ltd. (*E. A. Satchell; C. T. Barber.*)

HEARNE, William Alfred, plant supervisor, Messrs. Berry Wiggins Ltd. (*J. Swiss; G. H. D. Holmes.*)

HUNTER, William John Spencer, technical representative, Shell-Mex & B.P. Ltd. (*H. W. Clark; H. E. Priston.*)

LIST, William Frederick, director, Messrs. C. C. Wakefield & Co. Ltd. (*G. H. Thornley; L. G. Packham.*)

MOULAND, Walter Henry, process shift superintendent, Anglo-American Oil Co. Ltd. (*F. Mayo; J. R. Baddiley.*)

RANDS, Denis Nigel, production trainee, British Malayan Petroleum Co. (*C. R. Middleton; D. Gow.*)

REID, Antony Stuart, chemist, Hoffman Mfg. Co. Ltd. (*E. A. Goodchild; R. E. Race.*)

RIGBY, Albert, shift leader, Petrochemicals Ltd. (*W. E. Huggett; E. J. Dunstan.*)

SCADDEN, Leslie William, shift superintendent, Anglo-American Oil Co. Ltd. (*F. Mayo; J. R. Baddiley.*)

TENNANT, Joseph Allan, assistant to Vice-President, Cameron Iron Works. (*S. L. Witard; F. Pritchard.*)

WAKELING, Roy Gerald, trainee driller, Bemner Well Drilling Co. Ltd. (*W. W. Donald; P. Hicks.*)

Transfers.

DEACON, John Hereward, technical advisor, Shell Petroleum Co. Ltd. (*G. W. Thackery; A. D. Cooper.*) (*Associate Member to Associate Fellow.*)

HIXON, Fred Ernest, chemical engineer, "Shell" Refining & Marketing Co. Ltd. (*F. H. Garner; F. Morton.*) (*Student to Associate Fellow.*)

JEWELL, John Christopher, research chemist, Messrs. C. C. Wakefield & Co. Ltd. (*E. A. Evans; N. E. F. Hitchcock.*) (*Member to Fellow.*)

DE PASS, Percy Harold Hamilton, production superintendent, Ecuador Oilfields Ltd. (*A. H. Fincham; B. M. Craig.*) (*Associate Member to Fellow.*)

STEPHINSON, Pat Howard, control laboratory chargehand, "Shell" Refining & Marketing Co. Ltd. (*H. Taylor; E. J. Labrum.*) (*Student to Associate Member.*)

WYLLIE, David, Senior Scientific Officer, R.N.S.S. (*S. E. Bowrey; Peter Kerr.*) (*Member to Fellow.*)

NEW MEMBERS.

The following elections have been made by the Council in accordance with the By-laws.

Elections are subject to confirmation in accordance with the By-laws.

As Fellows.

ASHFORD, R. O.
BROWN, R. A.
HELM, J.

Transferred from Member to Fellow.

CAMERON, I.

As Members.

BERKIN, J. P.
POWELL, T. S.
SYKES, W. G. S.

Transferred from Associate Member to Member.

STEED, C. E.

As Associate Fellows.

ADAMS, W. H.
BELL, C. O. R.
CARRINGTON, R. A. C.
FAGERHOLT, G. R.
ISITT, J. S.
JOHNSON, H.
JONES, W.
MITCHELL, J. G.
REILLY, T. G.
ROJAS, A.
RYGH, H.
VERNON, R. H.
WHITTON, J. S.

Transferred from Student to Associate Fellow.

WINTERBOTTOM, J. E.

As Associate Members.

GATTEGNO, R. J.
GRIGGS, M. A.
JERAMS, E. S.
JOHNSTON, J. W.
NIDDRIE, R. H.
SADLER, G. J.

As Students.

DUFFY, J. P.
LABBAUF, A.
MILLS, L. A.
MULBERRY, K. W.

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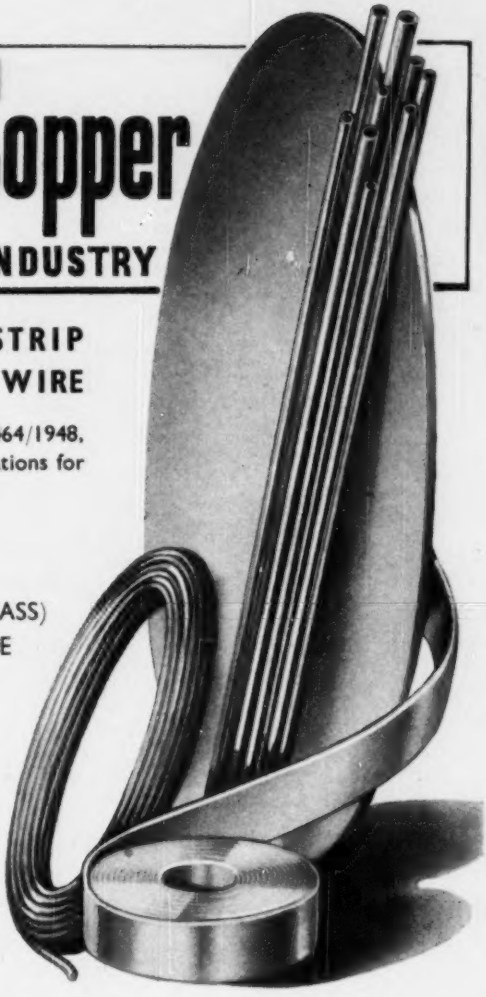

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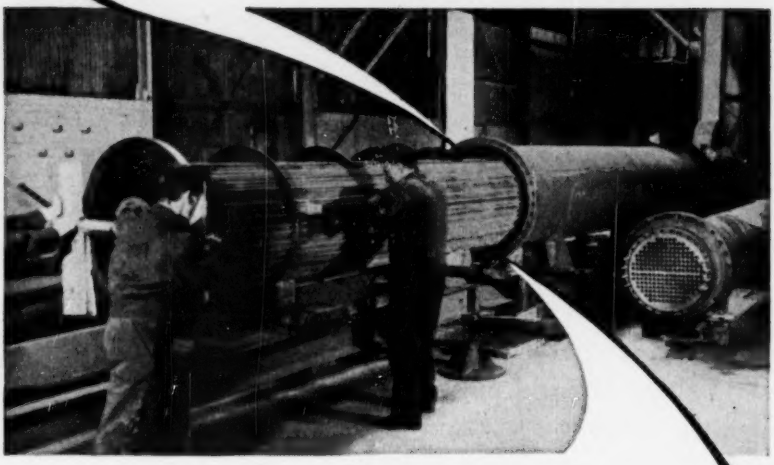

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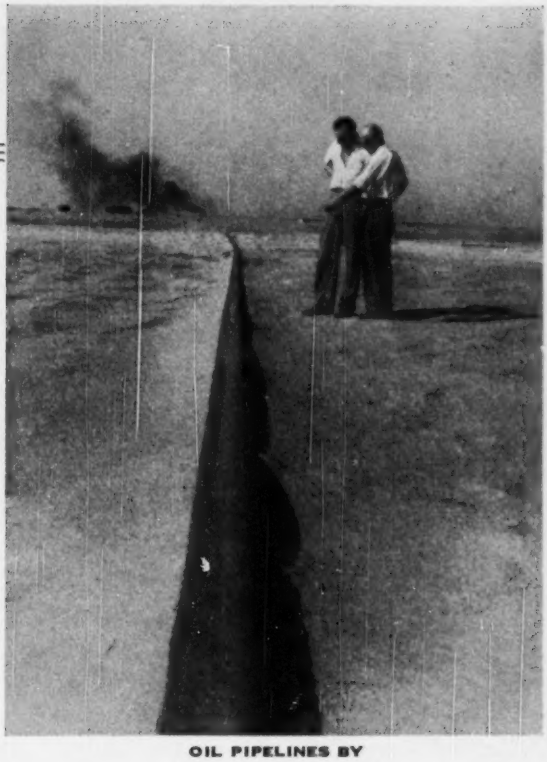

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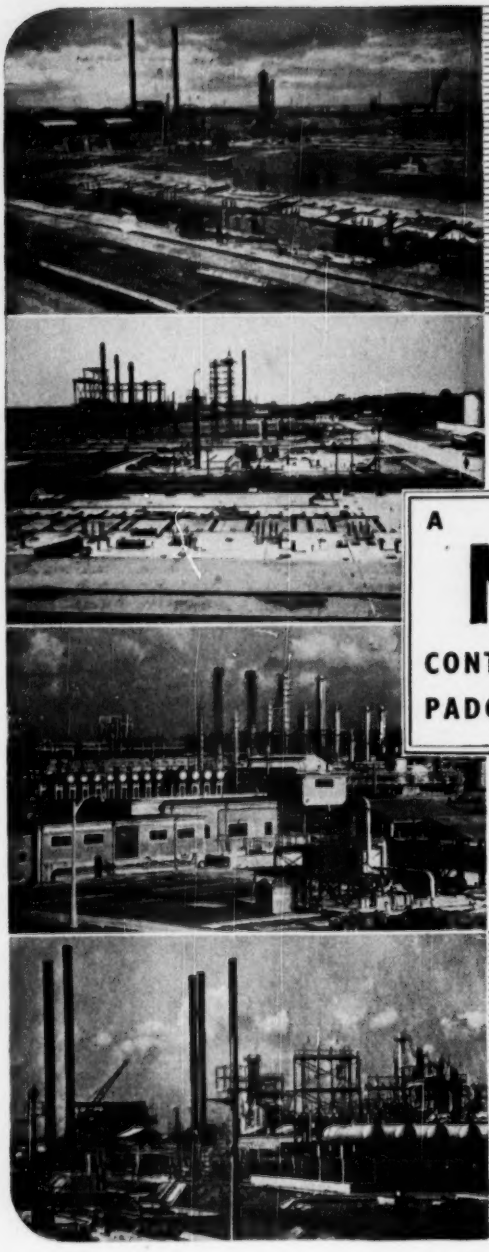

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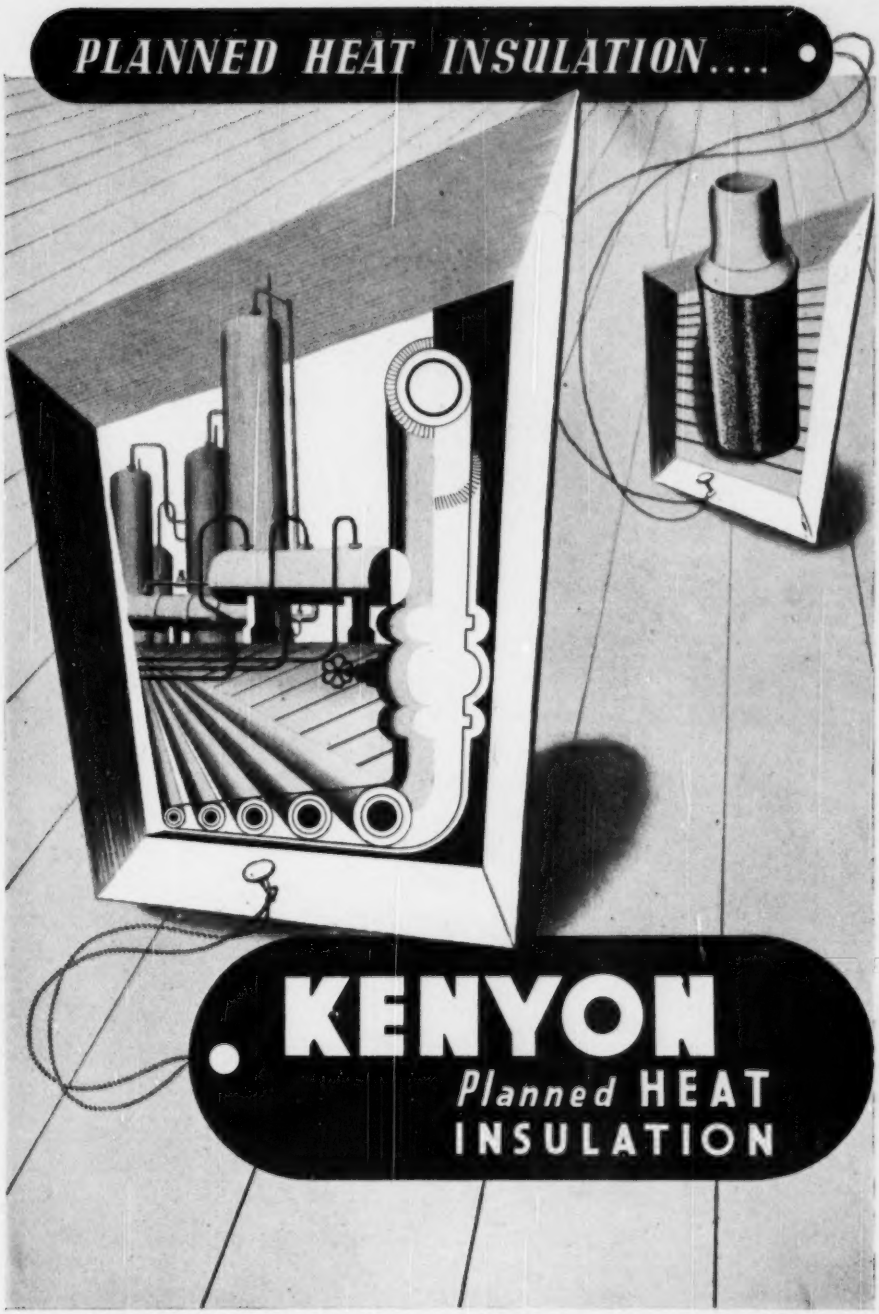

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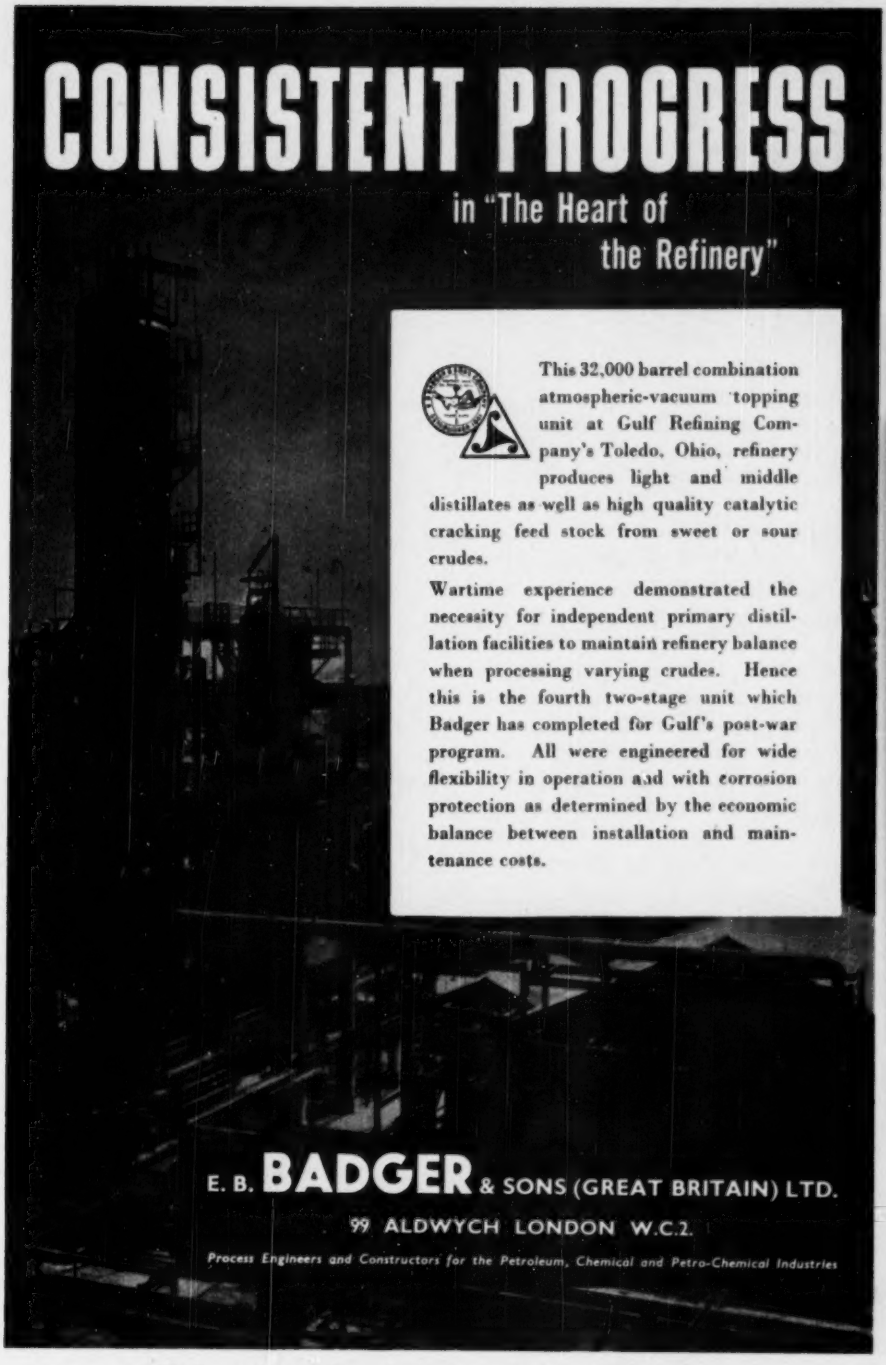
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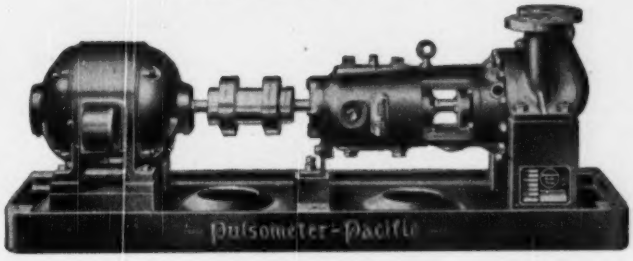

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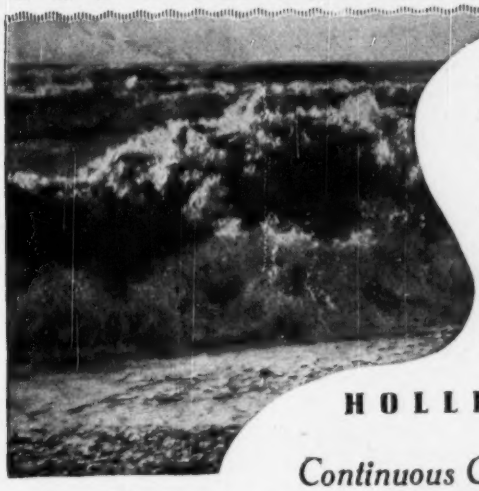

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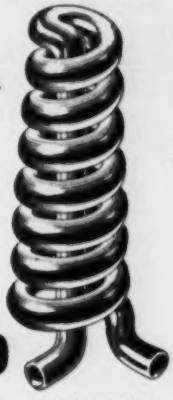

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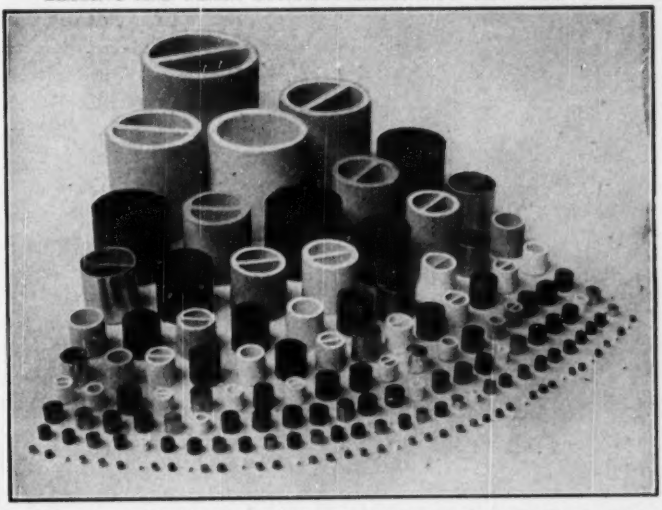

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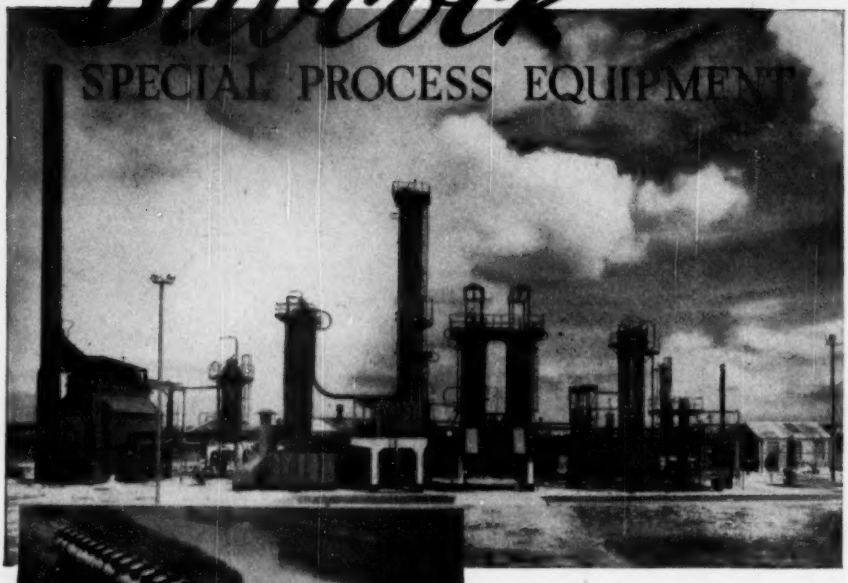

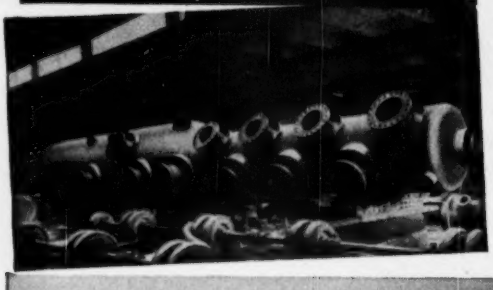

The illustration above shows a UOP Thermal Cracking Plant with Polymerization and Treating Units designed by Universal Oil Products Company. The major part of the pressure vessels was manufactured and erected by us to the order of Lobitos Oilfields, Ltd., Ellesmere Port, Cheshire.

To the left is shown a Depropanizer Tower 5′0″ dia. × 97′6″ high, weight 55 tons, leaving our Works. The bottom picture shows an Ammonia Fractionator 4′0″ and 6′6″ dias. × 41′3″ high, weight 21 tons, in course of construction. Both these vessels are for export.

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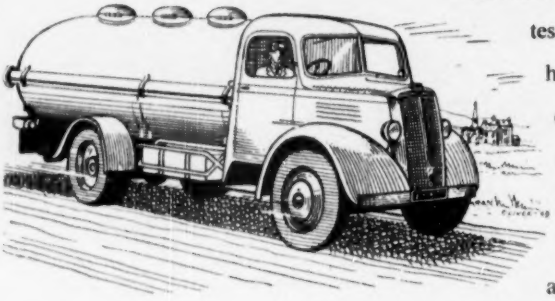

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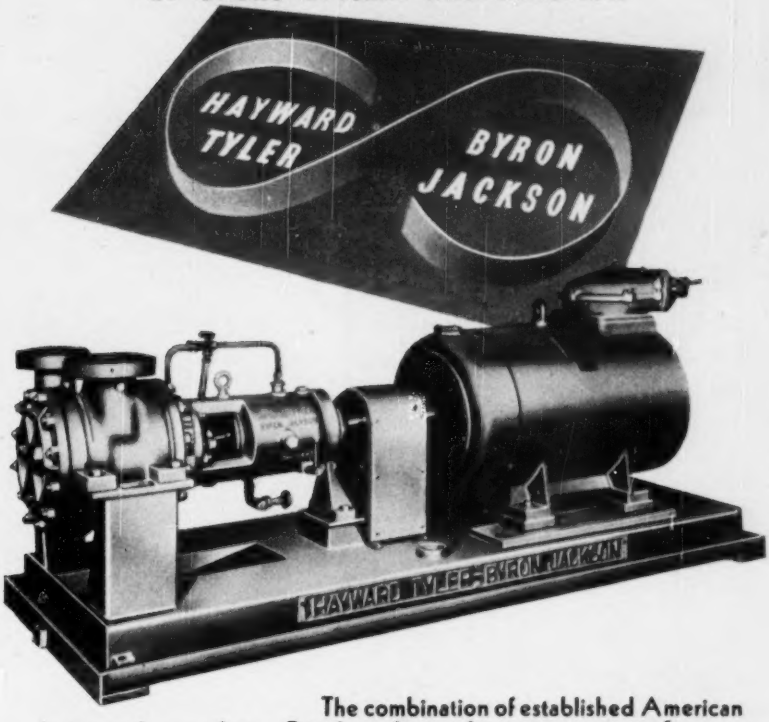

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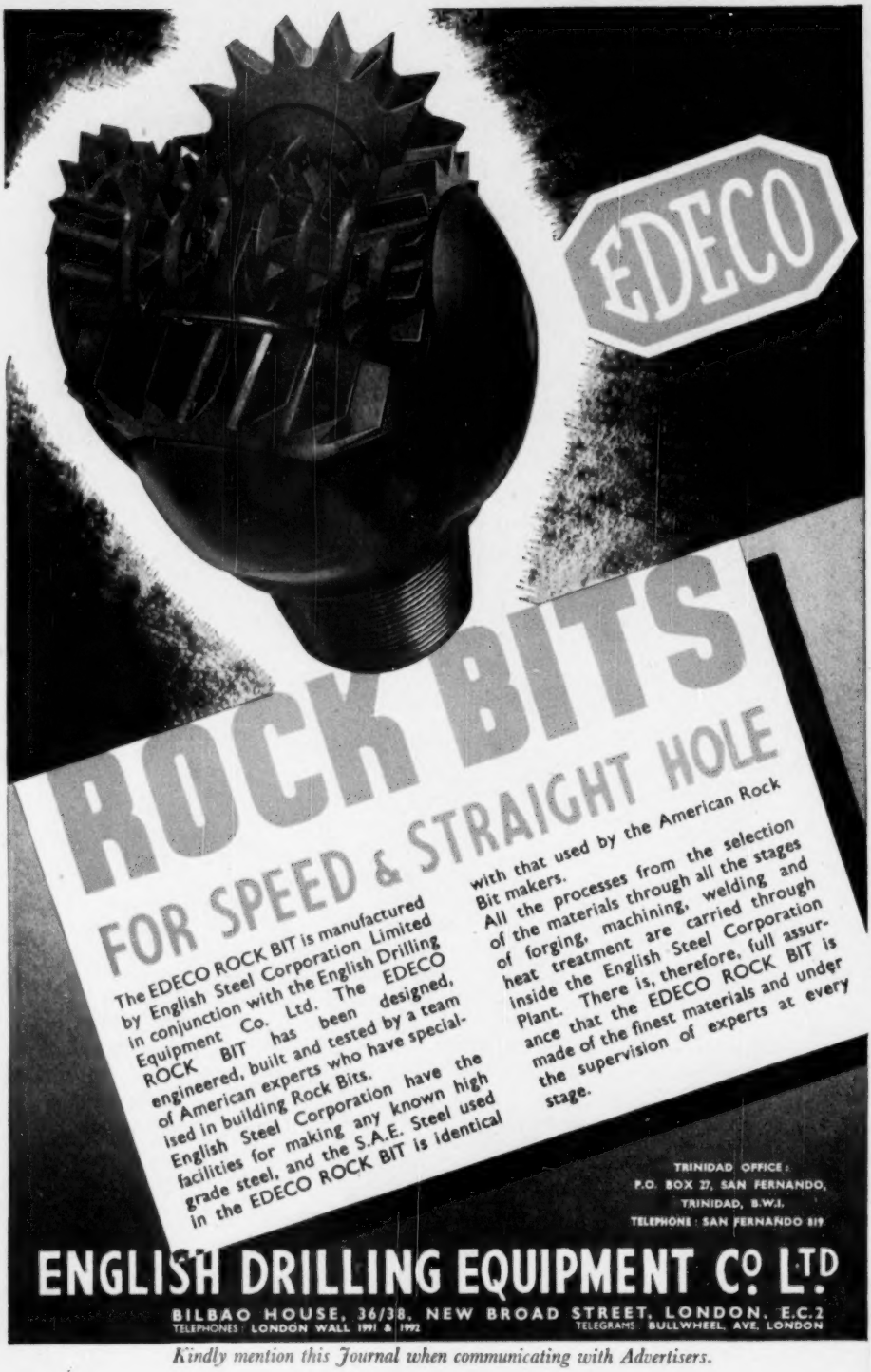
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